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Report on Elbow River
flood control

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REPORT ON

ELBOW RIVER FLOOD CONTROL

FOR
DEPARTMENT OF WATER RESOURCES
PROVINCE OF ALBERTA

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MONTREAL ENGINEERING COMPANY, LIMITED

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January 20th, 1966

Department of Water Resources
Terrace Building
Edmonton, Alberta

Attention: Mr. J. L. Reid
Supervisor of Hydro-Electric
Development

Elbow River Flood Control
File: AWR 1405-1; ER-200

Dear Sir:

In accordance with the request contained in your letter of 24th June, 1966, we submit herewith our report on measures required to control floods on the Elbow River in Calgary.

Our studies indicate that a major flood on the Elbow River will constitute a hazard to the property in the valley downstream of the Glenmore Dam. Until steps are taken to control the magnitude of the floods, a warning system, such as that proposed by T. Blench and Associates in their report of 14th March, 1961, should be considered. The warning would be given when the flow in the upper watershed had reached a predetermined value and would provide the opportunity for residents to move out of the danger area.

Our studies also indicated the possibility of a flood greatly in excess of that for which the Glenmore structures were designed. Hence, we have recommended that the dyke at the east end of the reservoir be raised five feet to safeguard it against overtopping in the event of a catastrophic flood. The main dam at Glenmore would also be overtopped in the event of such a flood, but we find it would be stable under the imposed loads. A flood of this magnitude would, of course, cause major damage in Calgary, even though the dam would be intact.

In our discussions during the reconnaissance of the Elbow it became evident that a firm recommendation for measures to alleviate the threat of damaging floods along the Elbow Valley in Calgary would require, as a prerequisite, a benefit-cost analysis. This would entail a detailed examination of property values and related matters which would prolong the study and add greatly to its cost, thus placing it outside of the range of expenditure you were prepared to make at this time. Hence, we agreed that our study would be directed towards establishing reasonable criteria for the limitation of flood flows and preparing preliminary estimates of the cost of structures required to achieve such control of flood flows. Once you were equipped with this information, you would then be in a position to judge what the next step

Department of Water Resources
Attention: Mr. J. L. Reid (Cont'd)

should be. Our study has followed this principle and I trust the findings will serve the purpose intended.

The costs of the proposed works are high, as had been anticipated. However, until they can be viewed in relation to the resulting benefits, it is not possible to judge whether they are unreasonably so.

If you find, on studying our report, that certain points need clarification or elaboration, we shall be pleased to discuss them with you.

It has been a pleasure to be of service to you and we are particularly grateful for your advice and co-operation and for the maps, reports and other data which you made available to us.

Yours very truly,

G.V. Eckenfelder

G.V. Eckenfelder
Manager Hydro Division

GVE/jh

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SCOPE OF REPORT

In accordance with instructions received from Mr. J. L. Reid, Supervisor, Hydro-Electric Developments, Alberta Department of Water Resources, in a letter dated June 24th, 1966, this report appraises the flood problems on:

a) The Elbow River

b) Fish Creek

The effects of various alternative flood protection schemes have been evaluated, and preliminary cost estimates prepared.

In accordance with a subsequent request by Mr. Reid, dated November 2, 1966, a study was made of the effects of a flood on the proposed development of the Calgary Stampede grounds in Victoria Park.

Also, in accordance with a further request, dated December 20, 1966, comments are made on the proposed bridge over the Elbow River at 1st Street S.E. Calgary.

Site work consisted of a helicopter reconnaissance of the Elbow River and Fish Creek valleys, along with a brief visit to the Glenmore Dam and Victoria Park.

FINDINGS

ELBOW RIVER FLOODS

In attempting to arrive at the most economic means of handling a flood on the Elbow River, the following alternative schemes were investigated:

Scheme 1 - Contain the flood within the Glenmore reservoir by raising the reservoir full supply level.

Scheme 2 - Contain the flood within the Elbow watershed by constructing upstream storage at the Mitchell damsite.

Scheme 3 - Contain the flood within a raised Glenmore reservoir and the Mitchell storage reservoir.

Scheme 4 - Pass the flood by constructing new spillway facilities from the Glenmore reservoir to the Bow River.

The aim of the study was protection against floods with a return frequency of 100 years or less. The first two schemes have certain physical characteristics which limit the amount of additional storage which can be created. Accordingly, Scheme 3 was developed as a combination of Schemes 1 and 2. The following table summarizes the various alternatives

None of the above schemes will provide full protection against a flood which would result from a storm similar to that which occurred in Montana in June 1964.

SUMMARY ALTERNATIVE SCHEMES FOR HANDLING ELBOW FLOODS

Scheme	Description	Protection against a flood with a Peak of cfs	Protection against a flood with a Frequency of	Resulting Flow Below Glenmore Dam cfs	Cost of Development
1	Riase Glenmore Reservoir to 3505	23,000	1 in 45	6,000	$1,900 000
2	Mitchell Storage Reservoir	22,500	1 in 45	6,000	$4,700 000
3	(1) + (2)	32,000	1 in 100	6,000	$6,600 000
4	Spillway, Glenmore to Bow	32,000	1 in 100	6,000	More than $12,700,000
-	No change	32,000	1 in 100	28,000	

ELBOW RIVER FLOODS (Cont'd)

In the course of investigating the effect of extraordinary floods, it was found that a storm equivalent to the 1964 Montana storm would, with the existing structures at Glenmore, cause the reservoir to overtop the east dyke. The main Glenmore dam would also be overtopped, but it is capable of safely withstanding the imposed load. A flood of this magnitude would cause indeterminate but widespread damage in Calgary, even though the dam would be intact.

FISH CREEK FLOODS

Flooding in the Fish Creek valley within the Calgary city limits will not become a problem, provided real estate developments are prevented from encroaching on the Fish Creek flood plain.

VICTORIA PARK

Flooding of Victoria Park will commence at flows in excess of 6,000 cfs on the Elbow River. Any diversion of the Elbow River within the Park, or construction of bridges across the river, which restrict the flow above that of the natural channel, will increase the flood hazard upstream of Victoria Park.

1ST STREET S.E. BRIDGE

The layout of the bridge as shown on City of Calgary Drawing 3-K-44, dated December 9th, 1966, is adequate for a flow in the Elbow River of 6,000 cfs. Larger flood flows will be restricted by the bridge and will find relief by washing out the bridge approaches.

RECOMMENDATIONS

ELBOW RIVER FLOODS

1. A warning system should be established to guard against flash floods on the Elbow River.

2. Appropriate action to provide flood protection to property downstream of Glenmore Dam is dependent upon the value assigned to the property. Such valuation is beyond the scope of this report, and so it is not possible to offer a recommendation. However, the significant figures quoted under "Findings" are here repeated in condensed form as a guide in evaluating the protection which could be afforded and its estimated cost. In each case the flood would normally be limited to 6000 cfs, at which flow little or no damage would occur to existing property. The probability of such protection being ineffective would correspond to the flood frequencies shown; for instance, if Scheme 1 were adopted, the probability of occurence of a flood in excess of 6000 cfs would be 0.02.

SCHEME NO.	PROTECTION AGAINST A FLOOD WITH A FREQUENCY OF:-	COST OF PROTECTION
1	1 in 45	$1,900,000
2	1 in 45	$4,700,000
3	1 in 100	$6,600,000

Even if none of the flood control provisions considered in this report are built, the east dyke at Glenmore Reservoir should be raised to el. 3512.5, five feet above the existing crest. This would provide 3.5 ft of freeboard during a flood of 90,000 cfs such as would be produced by a storm equivalent to that which occurred in Montana in 1964 and would thus prevent overstopping and failure of the dyke.

FISH CREEK FLOODS

3. Construction in the Fish Creek flood plain within the Calgary city limits should be prohibited.

RECOMMENDATIONS (Cont'd)

VICTORIA PARK

4. Bridges over the Elbow River at Victoria Park must not restrict the flow of the river above that of the natural channel. In order not to aggravate the effect of floods of 6000 cfs, bridges having a minimum flow area of 900 ft^2 at 8 ft water depth would be required. Floods in excess of 6000 cfs will in any event overtop the banks. A depressed channel, free of buildings, built through Victoria Park should be considered as a means of reducing the damage caused by overtopping the banks. The capacity of such a channel would depend upon the value of the property it protected. If one of the flood protection schemes considered in this report were adopted, the need for a by-pass channel would be doubtful. In this event, Victoria Park installation would enjoy the degree of protection afforded by the scheme adopted.

1ST STREET S.E. BRIDGE

5. The bridge abutments are supported on bearing piles only on the river side. It is recommended that the entire mass concrete abutment be supported on bearing piles, to facilitate repairs of the bridge in the event of a washout of the bridge approaches.

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PART I

ANALYSIS OF FLOOD PROBLEM

1. ABBREVIATIONS

Throughout this report the following abbreviations are used:-

acre-foot (feet)	acre ft
cubic feet per second	cfs
elevation	el
foot (feet)	ft
square mile(s)	sq mile(s)
year(s)	yr(s)
full supply level	fsl
low supply level	lsl

2. FIELD RECONNAISSANCE AND PRELIMINARY CONSIDERATIONS

On August 4, 1966, Mr. J.L. Reid and Mr. G.V. Eckenfelder of Montreal Engineering Company Limited made a helicopter flight of the Elbow from its mouth to the junction of Elbow and Little Elbow, (hereafter called "The Forks") some 7 miles above Elbow Falls, and down Fish Creek from above Priddis to its mouth. The Fish Creek reconnaissance included Priddis Creek which rises in the vicinity of the Elbow near Bragg Creek settlement. Maps used were 1:250,000 sheets,Calgary, 82-O and Kananaskis, 82-J. The area covered by the helicopter flight is shown on Plate 1.

(a) Elbow River Above Glenmore Dam

From about 5 miles above the Forks, the Elbow flows in a gravel-filled valley about 2000 to 3000 ft wide, then enters about 2 miles of narrow winding gorge where the mountain walls crowd in. The gorge sides rise steeply for at least 150 ft and are mainly talus on the lower slopes, but with numerous rock spurs projecting through the talus. The upper walls are bare rock. The river bed is paved with large slabs of rock and bedrock is probably at a shallow depth. This is the storage damsite described in the Mitchell Reports, which will be referred to as the "Mitchell Damsite". (Refer to Appendix I, Reference 1). This reach provides the only attractive storage possibility seen.

2. FIELD RECONNAISSANCE AND PRELIMINARY CONSIDERATIONS (Cont'd)

(a) Elbow River Above Glenmore Dam (Cont'd)

Below the gorge the valley opens and for 5 miles the river flows over rock between cliffs varying from 25 to 75 ft high. Elbow Falls is in this reach. Thereafter the valley floor widens and remains wide with only occasional constrictions until the settlement of Bragg Creek is reached. In this reach the mountains give way to foothills. There is a forestry station, Elbow Ranger Station, about 11 miles upstream of Bragg Creek which is accessible by a good gravel highway. A forestry road, newly rebuilt and mainly gravel surfaced, follows near the river above the Ranger Station and passes about one mile to the west of the Mitchell Damsite. A mile or two above Bragg Creek begins a series of summer houses, holiday camps and horse ranches, many of which have swimming pools and expensive stables. This development extends to the Bragg Creek settlement and some distance up Bragg Creek. There is a low divide between the head waters of Bragg Creek and the Jumping Pond watershed. By means of a dam on the Elbow in the vicinity of Bragg Creek settlement it appears feasible to divert excess water from the Elbow into Jumping Pond Creek and thence to the Bow River. However, the value of the property improvements affected by such a scheme would undoubtedly make it impractical.

Downstream of Bragg Creek, the river gradually emerges from the foothills and the river floor widens to between 2000 and 4000 ft. There is evidence of much gravel, but rock outcrops occur occasionally near the base of the banks. From Bragg Creek to about Pirmez Creek Ranch there is almost no cultivation in the river flood plain. In this reach the river crosses a part of the Sarcee Indian Reserve. Harris Creek provides a second low diversion route to the Jumping Pond watershed. This was examined by helicopter. It appears possible to dam the river just downstream of the mouth of Harris Creek, where the valley is about 3000 ft wide with 50 to 75 ft banks. The maximum water level would be limited either by the bank height or the Bragg Creek settlement. It would probably be necessary to open a canal through the height of land at the source of Harris Creek. If it were found necessary to investigate this scheme, photography and mapping would be required. A feasiblity study would require foundation borings.

Below Harris Creek the topography is unsuitable for diversion to the Bow River drainage. From the vicinity of Springbank Creek to Glenmore Reservoir there is an increasing concentration of farm buildings and cultivated land in the valley, at a low elevation. Some of the buildings and improvements are of high quality and any scheme involving flooding of the valley would incur considerable property costs. Moreover, the Sarcee Indian Reserve lands would be affected by such schemes.

2. FIELD RECONNAISSANCE AND PRELIMINARY CONSIDERATIONS (Cont'd)

(a) Elbow River Above Glenmore Dam (Cont'd)

Along the Glenmore Reservoir there are no buildings at low level and property damage caused by raising the reservoir would not be a serious factor unless the water level were such as to encroach on the improvements noted in the previous paragraph.

(b) Elbow River, Downstream of Glenmore Dam

The Elbow from Glenmore Dam to the confluence with Bow flows in an intensely developed valley containing high quality homes and apartments as well as commercial and industrial buildings. It is many years since a serious flood occurred and during the subsequent period properties have been improved and new buildings erected. Consequently, the potential damage by a major flood has become a matter of concern to the City of Calgary.

In 1966, as there was no recent data on the effect of high flows on the adjoining properties, the City authorities, at Mr. Reid's suggestion, released 5000 cfs from Glenmore reservoir and noted the effect. It was concluded that this flow caused no detectable damage, but it was estimated that at 5500 cfs some basement flooding would occur. Thus if it were desired to protect the area against all flood damage, provisions would have to be made to limit the discharge to 5000 or 6000 cfs. If, as it is reasonable to assume, full protection would not extend beyond floods with a return period of around 100 years, then floods in excess of this magnitude would result in a flow greater than 5000 or 6000 cfs.

(c) Fish Creek

There are no attractive sites for a flood storage reservoir on Fish Creek. The valley is partly in the Sarcee Indian Reserve, and above and below the latter, it is highly developed. There are numerous luxurious country homes, ranch facilities and cultivated lands, much of which would be affected by backing-up the stream. It would be possible however, to excavate a diversion canal, starting about 3 miles upstream of Priddis, and leading to Sheep River by way of Pothole and Three Point Creeks. Only a low diversion weir would be required across Fish Creek. This scheme would have the serious disadvantage of aggravating the danger of floods on the Sheep River and consequently it was not pursued. Moreover, as there is no appreciable property development in the Fish Creek valley within the City of Calgary, the need for protective measures is virtually non-existent. The obvious course for the City Authorities would be to restrict housing encroachment in the Fish Creek valley. The small valley would provide an excellent site for a park and it could be developed for recreation purposes. Mr. Reid agreed that investigation of Fish Creek need go no further.

3. DESIGN FLOOD SELECTION

The selection of a flood on which to base the design of flood protection projects is dependent on many factors which are difficult to evaluate. If too large a flood is selected, having a return frequency of say 1 in 10,000 years, the cost of flood protection becomes inordinately expensive. On the other hand, if too small a flood is selected, with a return frequency of say 1 in 20 years, the cost of the protection works may be very reasonable but the degree of flood protection provided will be small. There do not appear to be any well established criteria. In fact, experience in the United States indicates that the construction of flood protection works tends to encourage developments within the flood plain downstream, and these improvements are subject to inundation by floods smaller than those for which the protection works were designed.

It is evident that the cost of the flood protection works must bear some relationship to the value of the property which is being protected. Not knowing either of these values at the start of the study, it was decided to examine the significance of a flood having a return frequency of 1 in 100 years, which appears to be a reasonable point of departure, but which could be revised later if found necessary.

The 1 in 100 year flood has a peak flow of 32,000 cfs, as shown on Plate 2 which is 23% above the maximum recorded instantaneous peak of 25,200 cfs. The flood has a volume of 52,300 cfs-days which corresponds to a runoff of 4.12 inches on the drainage area. The flood hydrograph was patterned after the maximum recorded flood which occurred in 1932, and is shown on Plate 3.

As a comparison, the Winnipeg floodway is currently being constructed with a design capacity of 60,000 cfs plus 70,000 cfs in the river channel for a total of 130,000 cfs, or 26% above the record 1950 flood of 103,440 cfs. Thus the criteria selected for this study, namely a flood of 32,000 cfs with a return frequency of 1 in 100 years is supported by precedent in Western Canada.

The 5000 cfs water test release from the Glenmore Dam indicated that flooding would commence at a flow of about 6000 cfs. Accordingly it was decided to study flood control schemes which would provide protection against the 1 in 100 year flood while limiting the discharge in the river to 6000 cfs.

In the event of a flood greater than the 1 in 100 year flood, only partial protection would be achieved.

PART II

HYDROLOGY

1. ELBOW RIVER CHARACTERISTICS

The Elbow River rises on the eastern frontal ranges of the Rocky Mountains anf flows to the northeast and east, joining the Bow River within the Calgary city limits (Refer to Plate 1). The river has an overall length of about 60 miles with an average slope of 50 ft per mile. The drainage area is 471 sq miles and the average annual flow is about 330 cfs, or 0.7 cfs per sq mi.

In 1932 the Glenmore Dam was completed to provide a domestic water supply for Calgary. The reservoir is located near the mouth and contains approximately 18,000 acre ft of usable storage. The latter volume comprises 7.5% of the average annual flow.

2. EXISTING GLENMORE SPILLWAY FACILITIES

The existing spillway facilities at the Glenmore Dam consist of:

(a) an overflow spillway at el 3492.5 with a capacity of $Q=1170\ (h)^{3/2}$, where Q is the capacity in cfs and h is the depth of water over the sill in feet.

(b) two valves with a combined capacity of about 9000 cfs with the reservoir at el 3492.5.

The spillway discharge curves are shown on Plate 4.

The existing spillway and outlet valves have a combined capacity of 46,000 cfs (1). A check of the latter, with a head of 9 ft above the sill shows the combined capacity of the spillway and valves to be about 42,000 cfs. The latter is only about 30% in excess of the 1 in 100 year flood estimate of 32,000 cfs.

3. STREAM FLOW RECORDS

Stream flow records are available in the basin as outlined below in Table 1.

(1) From Reference 5 in Appendix 1.

3. STREAM FLOW RECORDS (Cont'd)

TABLE 1

Station on Elbow River	Drainage Area, sq miles	Maximum Recorded Flow, cfs	Average Flow, cfs	Period of Record
Bragg Creek	306	7,060(i)	390 (12 yrs)	1935 to date (open water)
Above Glenmore Dam	471	25,200(ii)	330(30 yrs)	June 1933 to date
Below Glenmore Dam	471	15,300(iii)	330(52 yrs)	1910 to 1932; 1933 to date

(i) average daily peak
(ii) instantaneous peak June 2, 1932
(iii) instantaneous peak June 3, 1929

4. FLOOD FREQUENCIES

The following Table 2 outlines the annual peak flows of the Elbow River at the Glenmore Dam and at Bragg Creek. The data, except for those at Bragg Creek, have been reproduced from the August 1965 report by T. Blench and Associates Ltd.

A statistical analysis of the flood peaks at the Glenmore Dam is shown on Plate 2. The flood with a recurrence interval of once in 100 years is indicated to be 32,000 cfs.

4. FLOOD FREQUENCIES (Cont'd)

TABLE 2

ELBOW RIVER FLOODS - CFS

Year	Date	Maximum Average Daily Flow, cfs			Instantaneous Peaks at Calgary and above dam	Bragg Creek average peak daily flow,
		at Calgary	above dam	below dam		
1908	June 2	5,615				
1909	June 3	3,320				
1910	Sept. 19	657				
1911	Aug. 8	3,159				
1912	June 16	4,312				
1913	Aug. 10	1,367				
1914	June 18	1,020				
1915	June 26	8,427			13,400	
1916	June 29	5,141				
1917	June 3	5,190				
1918	June 10	1,250				
1919	Aug. 6	2,559				
1920	July 13	2,392			2,475	
1921	May 25	1,317				
1922	May 17	935				
1923	June 1	11,700			14,200	
1924	June 29	1,880			2,202	
1925	June 12	2,350			2,530	
1926	June 20	2,230			3,490	
1927	June 10	2,940			2,990	
1928	June 19	3,540			3,810	
1929	June 3	13,500			15,300	
1930	May 31	1,080			1,140	
1931	June 18	795			999	
1932	June 2	12,900			25,200	
1933	June 16		1,085		1,505	
1934	June 10		862	1,192		
1935	June 19		1,030	1,156		
1936	June 2		1,136	1,259		

4. FLOOD FREQUENCIES (Cont'd)

TABLE 2 (Cont'd)

ELBOW RIVER FLOODS - CFS

Year	Date	Maximum Average Daily Flow, cfs			Instantaneous Peaks, at Calgary and above dam	Bragg Creek average peak daily flow,
		at Calgary	above dam	below dam		
1937	June 14		1,879	1,944		2,290
1938	Apr. 23		1,770	2,100		2,750
1939	June 17		3,200	3,690	4,320	2,640
1940	Sept. 6		1,283	1,425		750
1941	June 2		1,380	953		1,570
1942	May 11		4,500	4,510	11,060	7,060
1943	Apr. 4		1,100	1,230		1,560
1944	June 13		844	935		809
1945	June 1		2,635	2,386	2,950	3,780
1946	June 7		1,790	1,910	2,000	1,500
1947	May 11		2,406	2,799	2,770	2,140
1948	May 23		4,470	5,440	9,150	6,480
1949	May 22		695	798		621
1950	June 16		1,240	1,165	1,350	1,562
1951	Aug. 31		4,845	5,373	6,030	2,916
1952	June 23		2,790	2,840	3,210	2,110
1953	June 4		4,670	4,380	5,890	4,170
1954	Aug. 25		1,700	2,110		1,390
1955	May 20		1,620	1,650		1,310
1956	July 4		1,320	1,311		1,090
1957	June 9		1,074	1,362		1,020
1958	July 14		1,940	1,950		1,340
1959	June 27		1,740	1,980		1,410
1960	June 4		1,060	1,070		1,020
1961	May 27		1,900	1,880		1,800
1962	June 30		980	1,087		921
1963	June 30		4,370	3,500	6,310	3,980
1964	June 9		2,220	2,480	2,700	3,160
1965	June 18		3,670	3,520		4,430

5. FLOOD ROUTING - EXISTING CONDITIONS

In order to examine the effects of the 1 in 100 year design flood discharge at the Glenmore Dam, two alternative reservoir elevations 3492.5 and 3482.5, were assumed to exist at the beginning of large floods. The latter elevation was selected on the premise that warning of an approaching flood would be given up to one day in advance of the arrival of the peak at Glenmore Dam, thus permitting the operator to lower the reservoir 10 ft from the normal operating level 3492.5. The reservoir volume in the top 10 ft is 4000 cfs-day. Depending on the antecedent inflow, something less than a day's warning would permit the operator to withdraw the assumed 10 ft of storage by use of the valves.

Alternatively, a lower level than 3492.5 could be maintained until all danger of large floods were past. This would offer a small additional flood storage volume but would jeopardize the continuous water supply to the City of Calgary, since in low runoff years the reservoir might not fill subsequent to the flood season.

Above el 3492.5, the Glenmore reservoir has a volume of about 500 cfs-days per ft which contributes only a small reduction in the peak discharge. As stated previously, the existing spillway is at el 3492.5 and if there are no flash boards in place, it has a discharge relationship of $Q = 1170h^{3/2}$.

The following Table 3 outlines the results of flood routing the 1 in 100 year flood under existing conditions.

TABLE 3

1:100 YEAR FLOOD ROUTING

EXISTING CONDITIONS

Spillway Elevation ft	Initial Reservoir Elevation ft	Maximum Reservoir Elevation ft	Peak Spillway Discharge cfs	Valve Outflow cfs	Total Peak Discharge cfs
3492.5	3482.5	3499.6	22,000	6,000	28,000
3492.5	3492.5	3500.2	24,800	6,000	30,800

The peak discharges shown above exceed by several times the allowable 6000 cfs. It is evident that Glenmore reservoir, in its present form, has little value as a flood control device. Area and storage volume curves are shown on Plate 5.

6. ALTERNATIVE FLOOD PROTECTION SCHEMES

At the outset of the study, and before proceeding with detailed hydrologic investigations of the Elbow River floods, various alternative schemes were selected for examination, as follows:-

Scheme 1 - Raise Glenmore Reservoir

By increasing the storage capacity of the Glenmore reservoir, and reserving this capacity for flood storage, a greater proportion of a flood could be retained in the reservoir than is the case at present. Two alternatives were selected; increasing the Glenmore spillway elevation from 3492.5 to 3505.0, and to 3515.0.

Scheme 2 - Mitchell Storage Reservoir

By providing flood storage upstream of the Glenmore Dam at the Mitchell Site, the flood at Glenmore would be reduced in magnitude. The reservoir full supply level was selected after an inspection of the site topography.

Scheme 3 - Raise Glenmore and provide Mitchell Storage

Scheme 1 and 2 above could both be built.

Scheme 4 - Spillway Chute from Glenmore Reservoir

Instead of constructing storage facilities to retain a flood, additional spillway capacity could be provided for the Glenmore reservoir in the form of a chute spillway, discharging excess flood waters into the Bow River.

7. FLOOD ROUTING - SCHEME 1

A trial flood routing computation was carried out to determine the effect of raising the spillway sill elevation of the existing Glenmore Dam, but at the same time maintaining the present normal operating levels, except in times of flood.

The following Table 4 summarizes the results for the 1:100 year flood.

7. FLOOD ROUTING - SCHEME 1 (Cont'd)

TABLE 4

1:100 YEAR FLOOD ROUTING

RAISING GLEMMORE DAM

Spillway Elevation ft	Initial Reservoir Elevation ft	Maximum Reservoir Elevation ft	Peak Over Spillway cfs	Valve Outflow cfs	Total Peak Discharge cfs
3505	3482.5	3510.3	14,200	6,000	20,200
3505	3492.5	3511.4	19,200	6,000	25,300
3515	3482.5	3517.5	4,800	6,000	10,800
3515	3492.5	3519.8	12,000	6,000	18,000

The results in Table 4 indicate a significant reduction in peak discharge, but nevertheless the smallest discharge indicated above is 10,800 cfs which is still well above the maximum of 6000 cfs required to avoid damage downstream.

High reservoir elevations would be undesirable since the bottom of the upstream causeway bridge girder is at el 3507 and the roadway is at el 3513. Hence it was concluded that the spillway sill elevation should not be increased beyond 3505.0. A further caculation was made to determine the magnitude of flood which this small increase in storage could accommodate, with a maximum discharge of only 6000 cfs. This was found to be a flood having a peak of 23,000 cfs and a return frequency of 1 in 45. This assumes the reservoir at el 3482.5 at the beginning of the flood.

8. FLOOD ROUTING - SCHEME 2

A number of flood routing calculations were then carried out with the existing Glenmore reservoir in combination with a storage dam at the Mitchell Site upstream. The latter reservoir would provide a flood storage volume of approximately 32,000 acre ft and would control the upper third of the drainage area. The reservoir volume and area curves are shown on Plate 5.

8. FLOOD ROUTING - SCHEME 2 (Cont'd)

The 1 in 100 flood hydrograph was estimated as shown on Plate 6. As may be observed the flood on the river upstream of the Mitchell Site was estimated to have a peak of 10,000 cfs while that produced by the lower portion of the watershed had a peak of 22,000 cfs.

The results of the flood routing computation are shown on the following Table 5.

TABLE 5

1:100 YEAR FLOOD ROUTING

EXISTING GLENMORE PLUS MITCHELL DAM

Spillway Elevation ft	Initial Reservoir Elevation ft	Maximum Reservoir Elevation ft	Peak Flow Over Spillway cfs	Valve Outflow cfs	Total Peak Discharge cfs
3492.5	3482.5	3496.7	9,600	6,000	15,600
3492.5	3492.5	3498.0	15,200	6,000	21,200

It will be seen that the resulting maximum discharge at the Glenmore Dam is 15,600 cfs, still well above the required maximum of 6000 cfs. Accordingly, a further calculation was made to determine the magnitude of flood which could be accommodated by the Mitchell storage and the existing Glenmore reservoir passing only 6000 cfs. This was found to be a flood having a peak of 22,500 cfs and a return frequency of 1 in 45 years. This assumes the reservoir at el 3482.5 at the beginning of the flood.

9. FLOOD ROUTING - SCHEME 3

Flood routing computations for the combination of a storage dam at the Mitchell Site and the raising of Glenmore Dam were carried out and the results are summarized in Table 6 below.

9. FLOOD ROUTING - SCHEME 3 (Cont'd)

TABLE 6

1:100 YEAR FLOOD ROUTING

RAISING GLENMORE PLUS MITCHELL DAM

Spillway Elevation ft	Initial Reservoir Elevation ft	Maximum Reservoir Elevation ft	Peak Flow Over Spillway cfs	Valve Outflow cfs	Total Peak Discharge cfs
3505	3482.5	3503.0	-	6,000	6,000
3505	3492.5	3507.9	5,800	6,000	11,800

The results of these computations indicate that the required maximum 6000 cfs discharge could be achieved with the Mitchell Site storage plus raising the Glenmore Dam to el 3505. The flood in-flow hydrographs and corresponding reservoir elevations are shown on Plate 6.

The controlled flood peak discharge at Mitchell Site was computed to be 4800 cfs. This also is shown on Plate 6.

10. FLOOD ROUTING - SCHEME 4

Referring to Table 3, it is apparent that a diverted flow of 22,000 to 25,000 cfs would be required to limit the spill below Glenmore Dam to 6000 cfs. Accordingly a spillway chute was designed to accommodate a flow of 25,000 cfs. The general arrangement of the diversion scheme is shown on Plate 12.

11. MAXIMUM PROBABLE FLOODS

It is normal practice to provide a spillway capacity considerably in excess of the 100 year flood for a reservoir such as Glenmore. For this reason it was found prudent to estimate the maximum probable flood and to check the capacity of the existing spillway facilities.

11. MAXIMUM PROBABLE FLOODS (Cont'd)

The 1 in 10,000 year flood has often in the past been selected as the normal design flood. A flood of this magnitude was usually extrapolated from a frequency analysis curve such as shown on Plate 2. On Plate 2, the 1 in 10,000 year flood is indicated to be in the order of 100,000 cfs. The danger of extrapolating flood flows from statistical plots having only a few flood peaks is well known and it is preferable to employ other means of estimating the maximum flood.

A comparison with maximum floods recorded on other rivers is useful, and such a plot is shown on Plate 7. This indicates that a flood of 50,000 cfs on the Elbow is comparable to all other flood peaks recorded in Alberta and Montana.

A more basic approach, consisting of a study of maximum storms, is now often used to determine the maximum runoff to be expected from a watershed. The design storm is derived by maximizing the largest storms that have occurred in the region and, if necessary, transposing these to the watershed under study.

In June 1964 an unusually heavy rainfall occurred in Montana. The detailed analysis of this storm has not yet been obtained by Montreal Engineering Company but the preliminary data have been studied. Isohyetals of the storm as it is reported to have occurred in Montana were transposed to the Elbow River watershed. The Isohyetals are shown on Plate 8. It was assumed that 90% of the rainfall would appear as runoff. This storm would produce a flood having an estimated peak of 90,000 cfs and a volume of 125,000 cfs-days.

The modified spillway with sill at el 3505 considered in this report has been checked to determine the performance of the reservoir during such a flood. Table 7 shows the resulting reservoir elevations and the discharge for the two intial reservoir elevations assumed throughout this report.

11. MAXIMUM PROBABLE FLOODS (Cont'd)

TABLE 7

MAXIMUM PROBABLE FLOOD ROUTING

WITH GLENMORE DAM BUILT AND MITCHELL DAM

Spillway Elevation ft	Initial Reservoir Elevation ft	Maximum Reservoir Elevation ft	Peak Spillway Discharge cfs	Valve Outflow cfs	Total Peak Discharge cfs
3505	3482.5	3515.5	39,500	10,000	49,500
3505	3492.5	3516.0	42,000	10,000	52,000

It will be seen by referring to Plate 9 and 10 that el 3520 proposed for the new dike at the east end of the reservoir would be adequate to contain this flood without overtopping. The modified non-overflow concrete section would however, be overtopped by 11 ft by a flood of this magnitude, an acceptable contingency in such a case.

If the maximum probable flood estimate of 90,000 cfs is assumed to occur with the Glenmore reservoir in its present form, a peak discharge of about 85,000 cfs would occur at Glenmore and the reservoir would rise to el 3509. The existing earthfill dike with a crest elevation of 3507.5 would be overtopped.

A flood of 75,000 cfs would cause the reservoir to rise to elevation 3506.5, or one foot below the existing crest.

A flood of 75,000 cfs, or greater would, of course, cause widespread damage in the Elbow Valley.

PART III

DESCRIPTION - FLOOD PROTECTION SCHEMES

AND

CONCLUSIONS

1. RAISING GLENMORE - SCHEME 1

The required increase in storage capacity of the Glenmore Dam to a spillway sill elevation of 3505 can be accomplished relatively simply by pouring mass concrete on the downstream face of the dam as shown on Plate 9 and by raising the earth dike at the east of the reservoir as shown on Plate 10.

In order to provide sufficient spillway capacity over the raised ogee section, the reinforced concrete arch bridge on top of the spillway would have to be removed. This bridge is no longer used as a main thoroughfare since completion of the causeway upstream of the dam.

The estimate shown on Table 8 is based on the Calgary Water Works drawings listed in Appendix I, Reference 6.

TABLE 8

COST ESTIMATE OF GLENMORE DAM MODIFICATIONS

Item	Estimated Cost	
Clearing	$ 3,000	
Demolition of dam bridge	150,000	
Raising of concrete dam	1,080,000	
Raising of side dam	280,000	
Sub-total Civil Works		1,513,000
Undistributed construction expense	150,000	
Special contingency	50,000	
Engineering	100,000	
Interest during construction	87,000	
Sub-total Overhead Cost		387,000
TOTAL PROJECT COST		1,900,000

2. MITCHELL SITE - SCHEME 2

The Mitchell Site is located on the Elbow River in Section 4, Township 22, Range 6 west of the 5th Meridian. Detailed topography of the Site was obtained from drawing N 1503 in the Ducane, Dutcher & Company Report dated 26th, June 1914. See Appendix I, Reference 2.

This report describes the damsite as follows:-

> "The Site selected for the location of the dam is at a point where the banks of the river form a narrow gorge. This gorge commences about 1500 ft from the dam; its natural features are such that the eastern bank forms a natural windshield for the dam, thus obviating to a great degree wave and ice pressure effect on the dam.
>
> Both sides of the gorge are composed of solid white limestone of the Devonian age. Both rims are well exposed, though bedrock in the river itself is not in evidence owing to a quantity of slide rock which covers it up. Judging from the slope of the rims and the rapid fall of the river immediately below the damsite, the depth of this slide rock in the bottom of the river should not be more than a few feet."

No drilling had been undertaken at the damsite, hence the foregoing statement must be viewed with this in mind.

The Site was examined briefly by helicopter during the field reconnaissance. No investigation work for possible sources of aggregates on earth fill dam materials has been made.

A proposed layout of the project is shown on Plate 11 using an earth fill as the main structure. A concrete lined diversion tunnel would be constructed, first to dewater the river bed behind a cofferdam, and later to be used as the permanent outlet conduit. The tunnel would have an emergency gate close to its upstream end, and a tainter-type control gate at the downstream end. The tainter gate would be used for control of the reservoir. A spillway would be located on the hillside above the tunnel, and the material excavated from the spillway channel would be used in the dam.

Alternative layouts for this site were prepared using a "thick" concrete arch dam, and a "thin" concrete arch. Both appeared to be of the same order of cost magnitude as the earth dam, hence a more detailed study of all three alternatives should be undertaken if this project is to proceed further.

In order to provide a power supply at the Site, an existing single phase power line would have to be converted to three phase for a distance of 7 miles, and a new line extended a further 5 miles to the Site. A 3 phase transformer would be required, stepping down from 69 kv to 23 kv at a substation 12 miles from the damsite.

2. MITCHELL SITE - SCHEME 2 (Cont'd)

The main statistics of the Site are:-

Dam crest elevation	4980 ft
Reservoir full supply level	4970 ft
Reservoir low supply level	4885 ft
Storage	26,000 ac-ft
Tunnel discharge capacity	
at fsl	6,860 cfs
at lsl	3,000 cfs
Spillway capacity	20,000 cfs

The following estimate, Table 9, must be regarded as preliminary, giving only a general order of magnitude of the cost involved. The estimate assumes that suitable borrow pits will be located close to the damsite.

2. MITCHELL SITE - SCHEME 2 (Cont'd)

TABLE 9

COST ESTIMATE OF MITCHELL SITE

Item	Estimated Cost	
Clearing	$ 20,000	
Roads and bridges	120,000	
Unwatering	400,000	
Dam, spillway	1,850,000	
Intake-outlet	650,000	
Buildings	50,000	
Hydraulic gates	340,000	
Sub-total Civil Works		$ 3,430,000
Power supply including transmission line and substation	$ 100,000	
Sub-total electrical works		$ 100,000
Undistributed expense	360,000	
Special contingency	270,000	
Engineering	250,000	
Interest during construction	290,000	
Sub-total overhead cost		$ 1,170,000
TOTAL PROJECT COST		$ 4,700,000

Access is by a Provincial forestry road to within 1 mile of the damsite. The estimate does not include any improvement of this road.

Estimates of a concrete arch dam layout ranged from a low of $ 4,000,000 to a high of $ 5,500,000 depending on the design of the arch and the unwatering facilities.

3. RAISING GLENMORE AND MITCHELL - SCHEME 3

This scheme is merely the addition of schemes (1) and (2). The estimated cost is therefore:-

Scheme 1	$ 1,900,000
Scheme 2	$ 4,700,000
Total (Scheme 3)	$ 6,600,000

4. CHUTE SPILLWAY - SCHEME 4

Instead of aiming to contain a flood within the Glenmore Dam watershed, an alternative would be to construct new spillway facilities to bypass the Elbow below Glenmore Dam and discharge flood waters into the Bow River, as shown on Plate 12.

The difference in elevation between the Glenmore reservoir and the Bow River is about 190 ft, hence a high velocity, concrete-lined spillway chute would be required. Since this type of structure is expensive, the most direct line from the reservoir to the river was chosen for a first trial estimate, without regard to real estate expropriation costs. The profile of the chute was arranged so that cross-streets could be carried on bridges above the chute without a grade change. At the railroad line and adjacent Highway No. 2, the chute would be well above grade and would require bridges over both highway and railroad.

The estimate in Table 10 does NOT include the following costs:

(a) Expropriation of land and real estate.

(b) Demolition of buildings.

(c) Relocation of services.

(d) Construction of bridges across spillway chute.

4. CHUTE SPILLWAY (Cont'd)

TABLE 10

COST ESTIMATE OF SPILLWAY CHUTE

Earth work	$ 1,000,000
Concrete	6,940,000
Control gates	220,000
Undistributed costs, contingencies and engineering	2,040,000
TOTAL	$10,400,000

Allowing for a 40 ft, right-of-way on either side of the spillway, the total area required to be expropriated is 62 acres. According to information obtained from City of Calgary maps and aerial photographs produced in 1959, about 40 acres were then unoccupied and the remainder contained some 100 residences. If the unoccupied land is assumed to cost $ 8,000 per acre and each residence with its land, $ 30,000, the cost of the land and residences would be of the order of $ 3,300,000. In addition there would be the cost of relocating services, construction of bridges and other indeterminate expenses which, together with the costs quoted in Table 10, would bring the total of Scheme 4 to several times that of Scheme 3. Accordingly, no further consideration has been given to this scheme.

5. ELBOW RIVER FLOOD - CONCLUSIONS

Since neither Scheme 1 nor Scheme 2 can protect the City of Calgary against the selected 1:100 design flood, and since the alternative chute spillway, Scheme 4, is excessively costly the only alternative worthy of consideration is Scheme 3, consisting of a new reservoir at the Mitchell Site and increasing the flood storage capacity of Glenmore, at an estimated total cost of $ 6,300,000. This estimated cost must be balanced against the cost of flood damage which the proposed structures would prevent. The implications of expropriating all properties within the probable flooded area might also be considered, although such a measure would undoubtedly be unacceptable to the public. These considerations are beyond the scope of this report. Whether or not flood control structures are built, a warning system such as proposed by T. Blench and Associates, (see Appendix I, Reference 4) will be an important safeguard.

5. ELBOW RIVER FLOOD - CONCLUSIONS (Cont'd)

In Section 14 is was shown that a flood of 90,000 cfs, produced by a rain equivalent to the Montana storm of June 1964, would cause the water in Glenmore reservoir to reach el 3509, 1.5 feet above the present crest of the east dike. Accordingly, even though no other flood protection provisions are undertaken, the dike should be raised to el 3512.5, thus providing 3.5 feet of freeboard under this extreme condition. The downstream slope of the dike has been used for dumping waste earth. This earth or additional waste, if available, could be used for raising the dike.

PART IV

VICTORIA PARK

AND

1ST STREET S.E. BRIDGE

1. VICTORIA PARK

A proposal has been made to reconstruct the race track at Victoria Park in a location which would entail diverting the Elbow River to make room for grandstands and other facilities. The track would cross the relocated river by means of two bridges.

Since the Elbow River will overflow its banks at a flow of about 6000 cfs the briges should be constructed so as not to interfere with the free flow of the river up to a discharge of 6000 cfs. This concept establishes the following minimum design criteria:-

Required free flow area	900 ft^2
Water depth	8.0 ft
Corresponding water level-about	el 3388.0
Corresponding flow	6,000 cfs

Plate 13 shows the flooded area in Victoria Park and downstream of the Glenmore Dam, which would exist in the event of large floods. However, at lesser floods, an indeterminate area in Victoria Park would be flooded. This has not been estimated, as the extent of flooding and the course followed by flood waters will be influenced by the size and location of buildings within the Park, the eventual redevelopment of which is not known in detail. It is recommended however, that in planning the redevelopment of the Park, consideration be given to providing an unobstructed depressed zone which would carry flood water in excess of 6000 cfs. The capacity of this "floodway" would be dependent upon its cost and upon the value of the property which it was intended to protect. In studying the effectiveness of such a floodway, it should, be borne in mind that it will cease to be effective beyond a certain undetermined flow. This will be dependent upon natural or man-made obstructions in the flood plain lying adjacent to and downstream of Victoria Park. The need for, and capacity of the floodway is also closely related to the scheme selected for flood control on the Elbow. If no flood control measures are adopted, the floodway assumes major importance; if Scheme 3 outlined in Section 15 through 17 were adopted, the need for the floodway would be doubtful. Thus, the redevelopment of Victoria Park should be closely coordinated with the measures taken to deal with the Elbow River floods.

2. 1ST STREET BRIDGE

A drawing (No. 3-k-44) of the proposed new 1st street East Bridge produced by the City of Calgary Planning Department shows a bridge having two 100 ft spans, with the underside of the span 12 ft above river bed level. This would be entirely adequate for a flow of 6000 cfs, and it is recommended that other bridges over the Elbow, such as those proposed for Bictoria Park be constructed to the same standard of flow area.

2. 1ST STREET BRIDGE (Cont'd)

If the measures outlined in this report are not adopted, or delayed, we would then recommend that the bridge be strengthened by the addition of bearing piles under the mass concrete abutments. In the event of a flood larger than 6000 cfs, the bridge approaches would likely be washed out, and, without the extra abutment bearing piles, the abutment support would be lost, allowing the bridge spans to collapse into the river bed.

The small extra cost of additional bearing piles would allow the abutments to be supported independently of the adjacent earthwork, and hence would greatly simplify the repair of the bridge in the event of a washout.

APPENDIX I

BIBLIOGRAPHY

APPENDIX I

BIBLIOGRAPHY

The following documents and drawings were used in the preparation of this report:-

1. Report to Dominion of Canada

   Hydro-Electric Power Potential Lower Canyon, Elbow River
   By C.H. Mitchell and P.H. Mitchell, dated August 15th, 1911.

2. Report on Proposed Hydro-Electric Development Elbow River, Alberta

   by Duncane, Durcher & Co., dated June 26th, 1914.

3. Report on Possible dam sites on Elbow River

   by R.T. Hollies, P. Eng., dated March 14th, 1961.

4. Flood Protection, Elbow River, Calgary

   by T. Blench & Associated Ltd., dated August 30th, 1965.

5. Article published in AWWA, Vol. 26, No. 8

   "Calgary New Water Works System", by W. Gore, dated August, 1934.

6. The following Calgary Water Works drawings:-

Title	Date	Dwg. No.
Glenmore Reservoir - Dam General Plant and Profile	June 18/32	R-3
Typical Sections Through Units as Constructed	Jan. 13/32 Jan. 14/32 Sept. 17/31 Dec. 16/31	R-19 R-20 R-21 R-22
Part of Sec. 32 - Twp. 23 - R.1 - W.5th & Part of Sec. 29 - Twp. 23 - R.1 - W.5th.	Mar. 22/33	Gr. 1
Part of Sec. 29 - Twp. - R.1 - W.5th and N½ of Sec. 20 - Twp. 23 - R.1 - W.5th	Mar. 22/33	Gr. 2

BIBLIOGRAPHY (Cont'd)

6. (Cont'd)

Title	Date	Dwg. No.
Part of Sec. 30 - Twp. 23 - R.1 - W.5th and N½ of Sec. 19 - Twp. 23 - R.1 - W.5th	Mar. 22/33	Gr. 3
Part of the Sarcee Indian Reserve West of Sec. 30 - Twp. 23 - R.1 - W.5th	Mar. 22/33	Gr. 4
Embankment in Sections 20 and 29 Twp. 23, Range 1, West of 5th Meridian		El. 1

7. The following City of Calgary drawings:-

Topographical series

Sections 17, 18, 19, 20
15, 16, 11, 22
13, 14, 23, 24

8. City of Calgary

1st Street Bridge	Dec. 9/66	3-k-44

JLG/jh

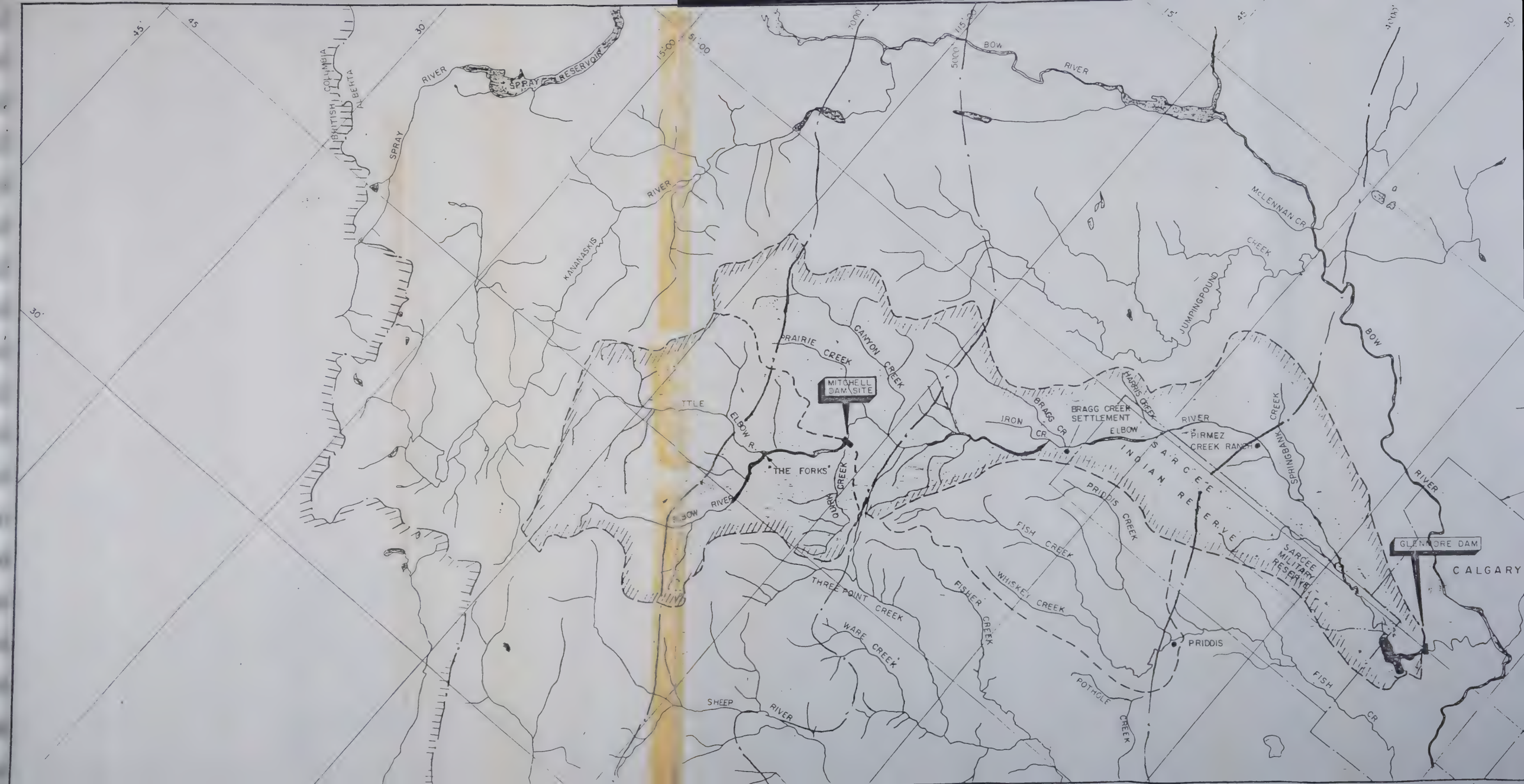
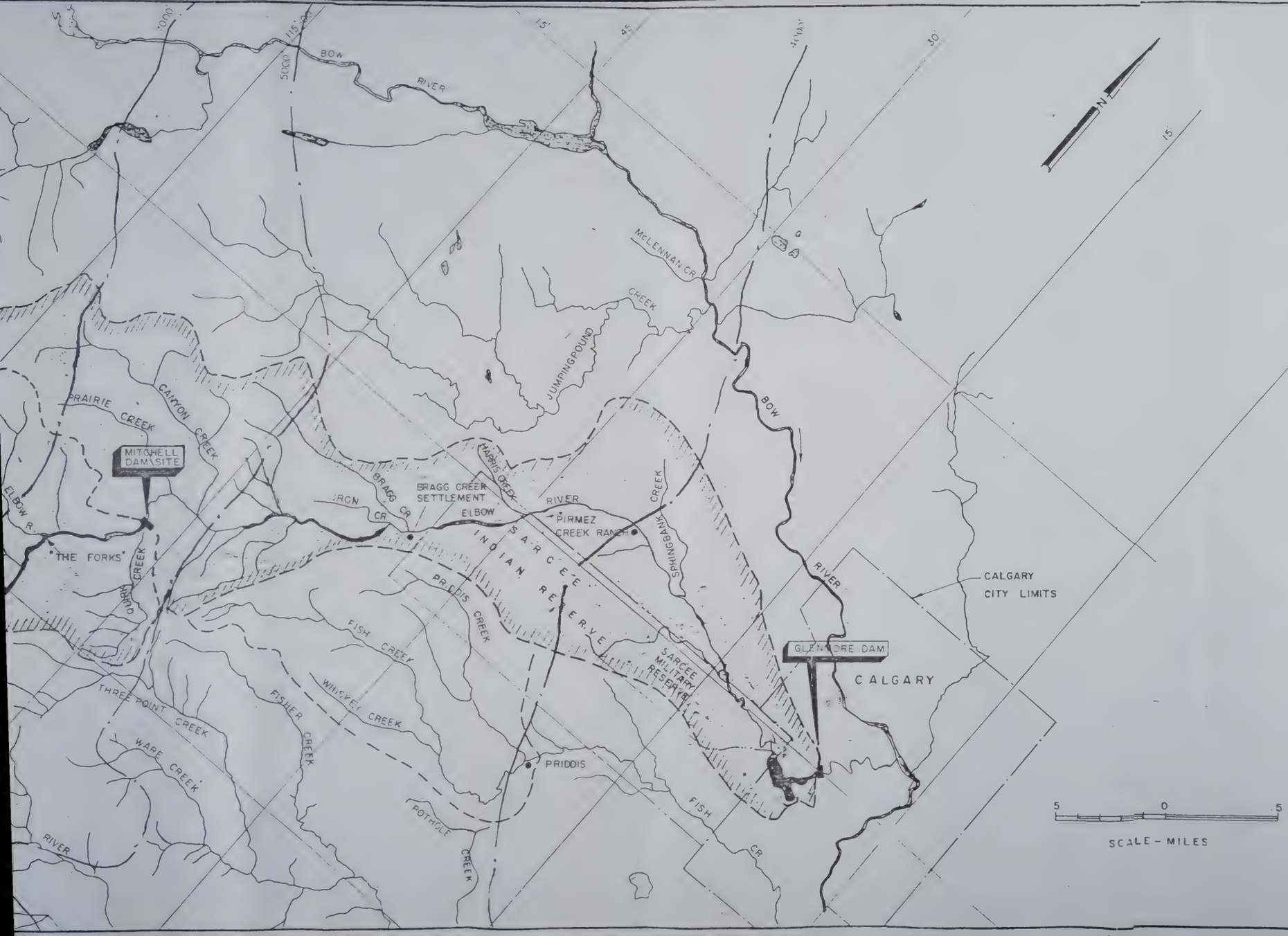

BRITISH COLUMBIA
ALBERTA
SPRAY RIVER
SPRAY RESERVOIR
KANANASKIS RIVER
BOW RIVER
MCLENNAN CR
JUMPINGPOUND CREEK
PRAIRIE CREEK
CANYON CREEK
MITCHELL DAM SITE
ELBOW R.
THE FORKS
QUIRK CREEK
BRAGG CR
IRON CR
BRAGG CREEK SETTLEMENT
HARRIS CREEK
ELBOW RIVER
PIRMEZ CREEK RANCH
SPRINGBANK CREEK
SARCEE INDIAN RESERVE
PRIDDIS CREEK
FISH CREEK
SARCEE MILITARY RESERVE
GLENMORE DAM
CALGARY
THREE POINT CREEK
WARE CREEK
FISHER CREEK
WHISKEY CREEK
PRIDDIS
POTHOLE CREEK
FISH CR
SHEEP RIVER

PLATE 1



LEGEND

APPROXIMATE ELEVATIONS

REFERENCE: NATIONAL TOPOGRAPHIC MAP 82J, & 82O

5 0 5

SCALE - MILES

MONTREAL ENGINEERING CO. LTD.

DEPARTMENT WATER RESOURCES
PROVINCE OF ALBERTA

ELBOW RIVER REGULATION

WATERSHED LOCATION

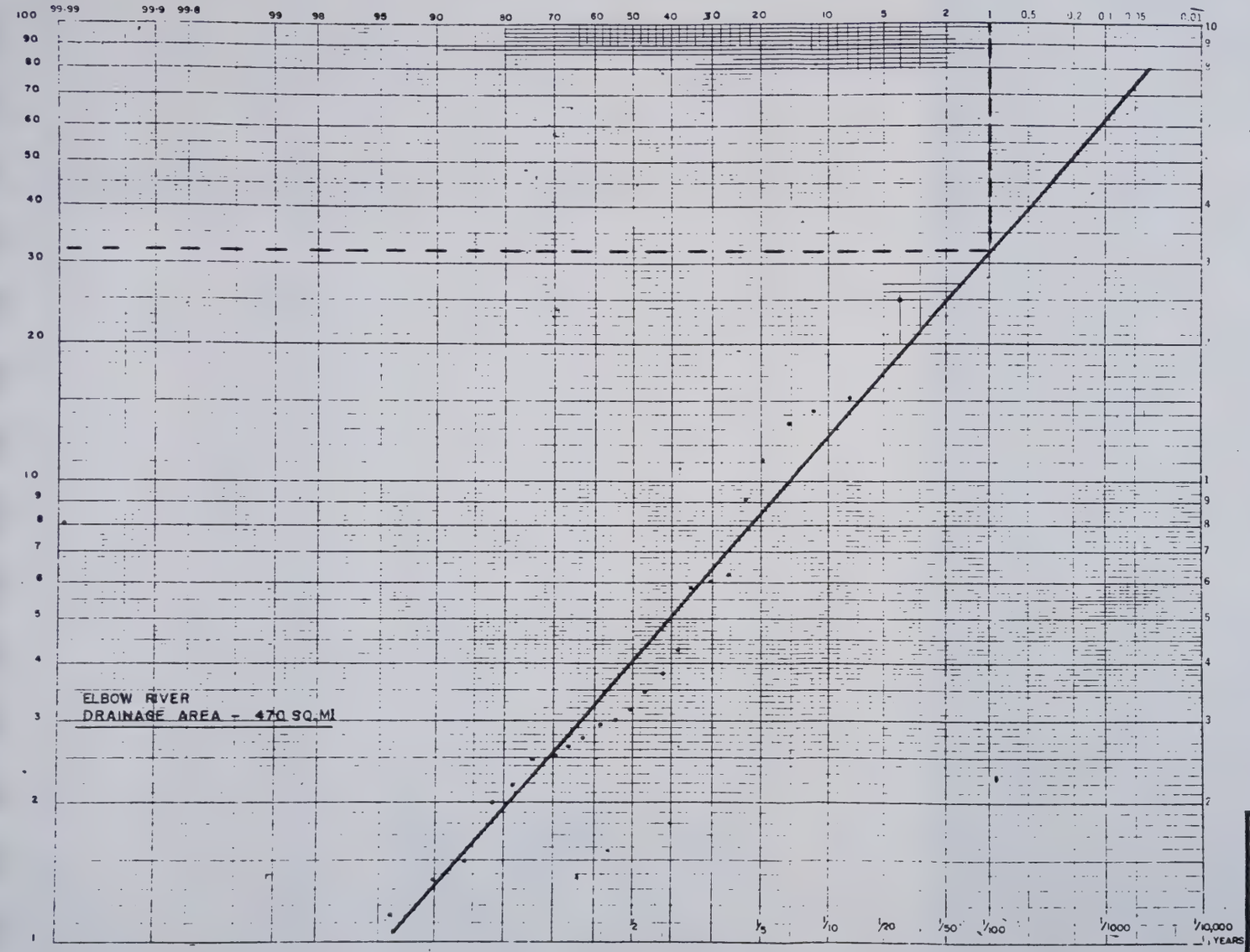
DESIGNED: G.D. DRAWN: C.B. DATE: OCT. 1966

SUPERVISOR: K.G.B PASSED: [signature]

W.O. No.: AWR-1405-1 SCALE: 1:250,000

DWG. NO.: D-AWR-1013-1

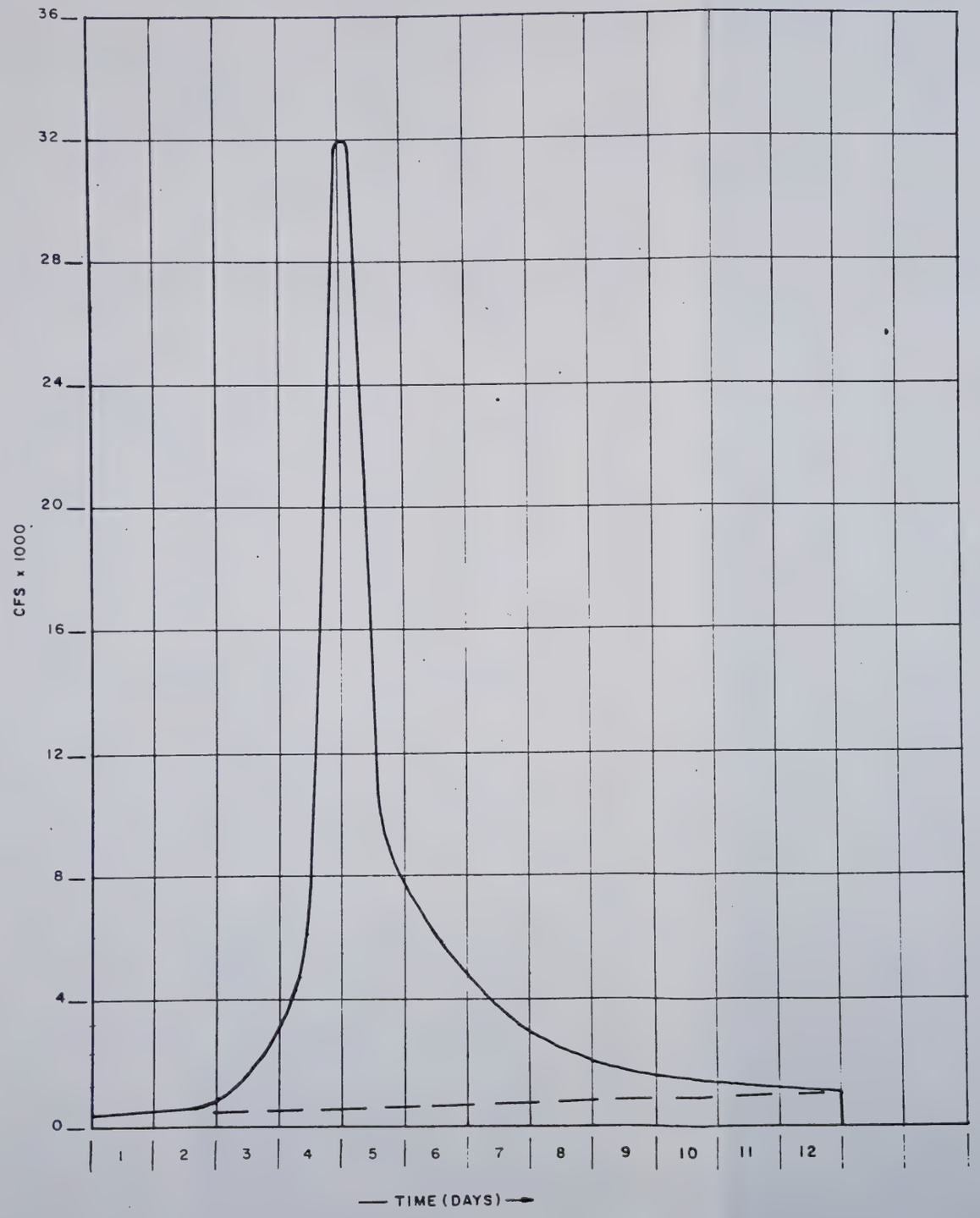
PLATE 2



This is Based on Instantaneous Peaks

MONTREAL ENGINEERING CO. LTD.
DEPARTMENT WATER RESOURCES PROVINCE OF ALBERTA
ELBOW RIVER REGULATION
Instantaneous FLOOD FREQUENCY ANALYSIS
DESIGNED: R.B. DRAWN: R.L. DATE: OCT. 1966.
SUPERVISOR: K.G.B. PASSED: Gerckenfelder
W. O. No.: AWR-1405-1 SCALE: —
DWG. NO.: C- AWR - 1013 - 2

PLATE 3



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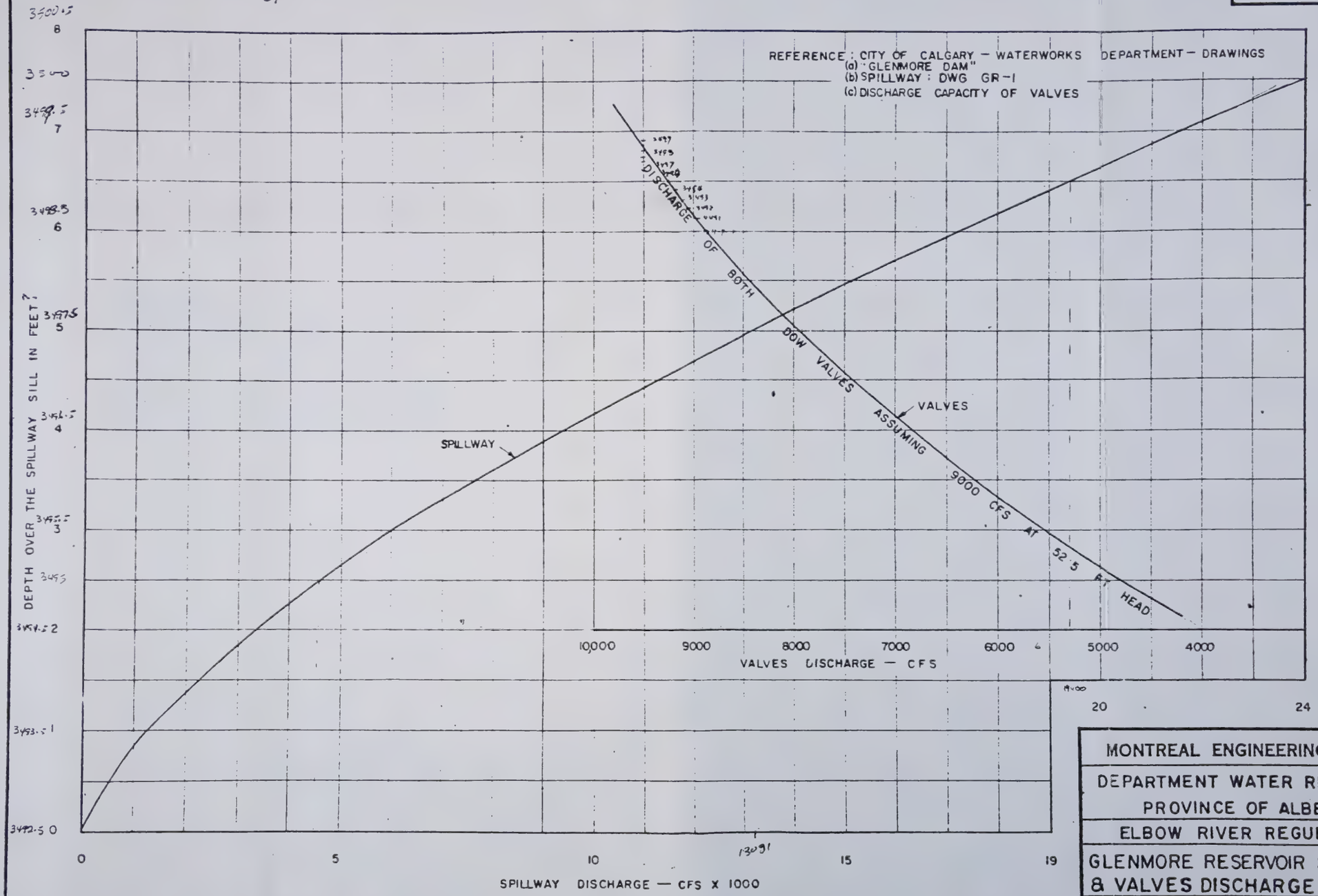
DEPARTMENT WATER RESOURCES PROVINCE OF ALBERTA
ELBOW RIVER REGULATION
1:100 YEAR FLOOD HYDROGRAPH
DESIGNED: R.B. DRAWN: R.L DATE: OCT. 1966
SUPERVISOR: K.G.B. PASSED: W.H. Scholfield
W. O. No.: AWR – 1405–1 SCALE: —
DWG. NO.: C- AWR - 1013 - 3

PLATE 4

$Q = 1170\ h^{\frac{3}{2}}$



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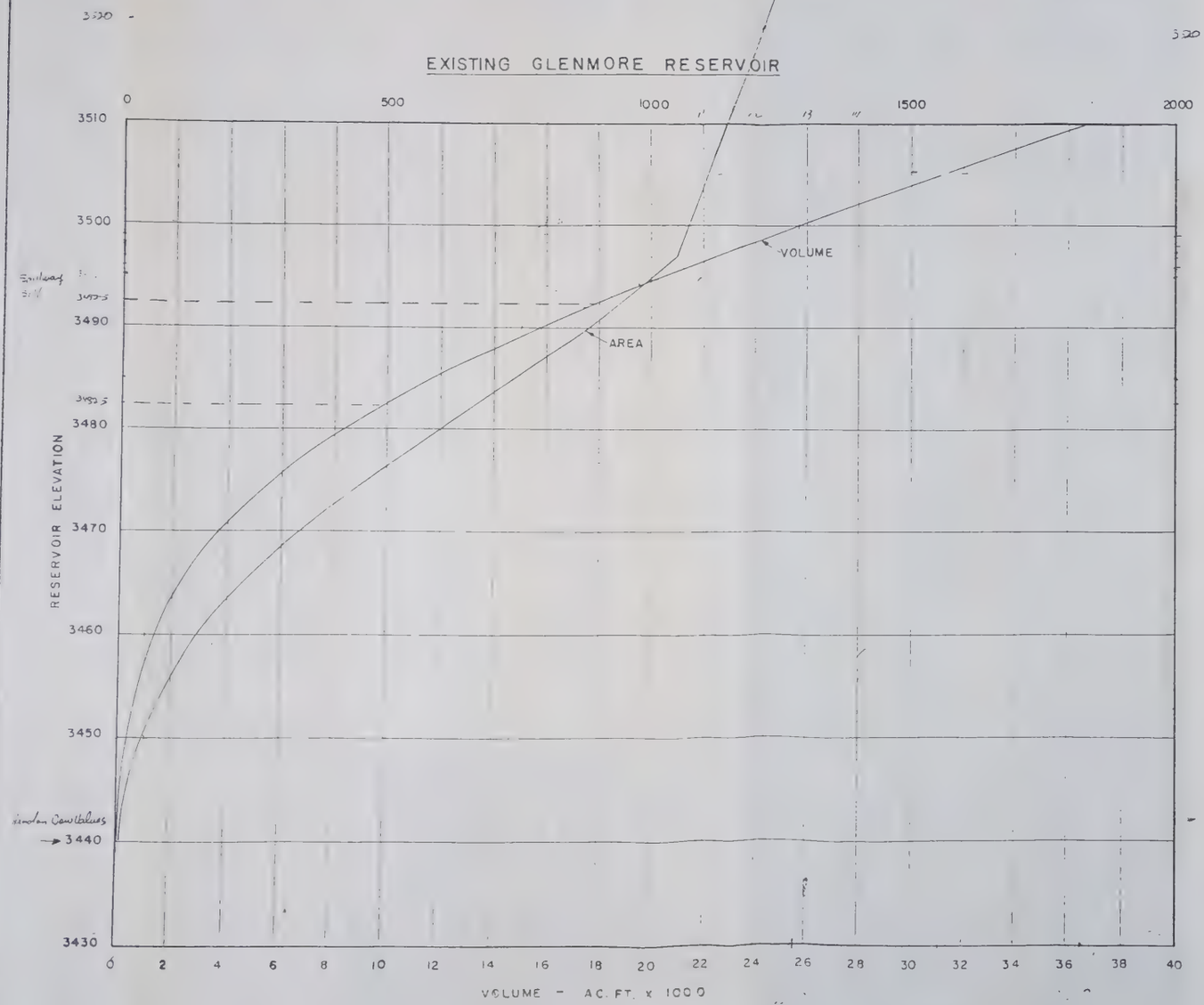
DEPARTMENT WATER RESOURCES PROVINCE OF ALBERTA	
ELBOW RIVER REGULATION	
GLENMORE RESERVOIR SPILLWAY & VALVES DISCHARGE CURVES	
DESIGNED: G.D.	DRAWN: C.B. DATE: OCT. 1966
SUPERVISOR: K.G.B.	PASSED:
W. O. No.: AWR-1405-1	SCALE: —
DWG. NO.: C-AWR-1013-4	

EXISTING GLENMORE RESERVOIR



POTENTIAL RESERVOIR AT MITCHELL SITE

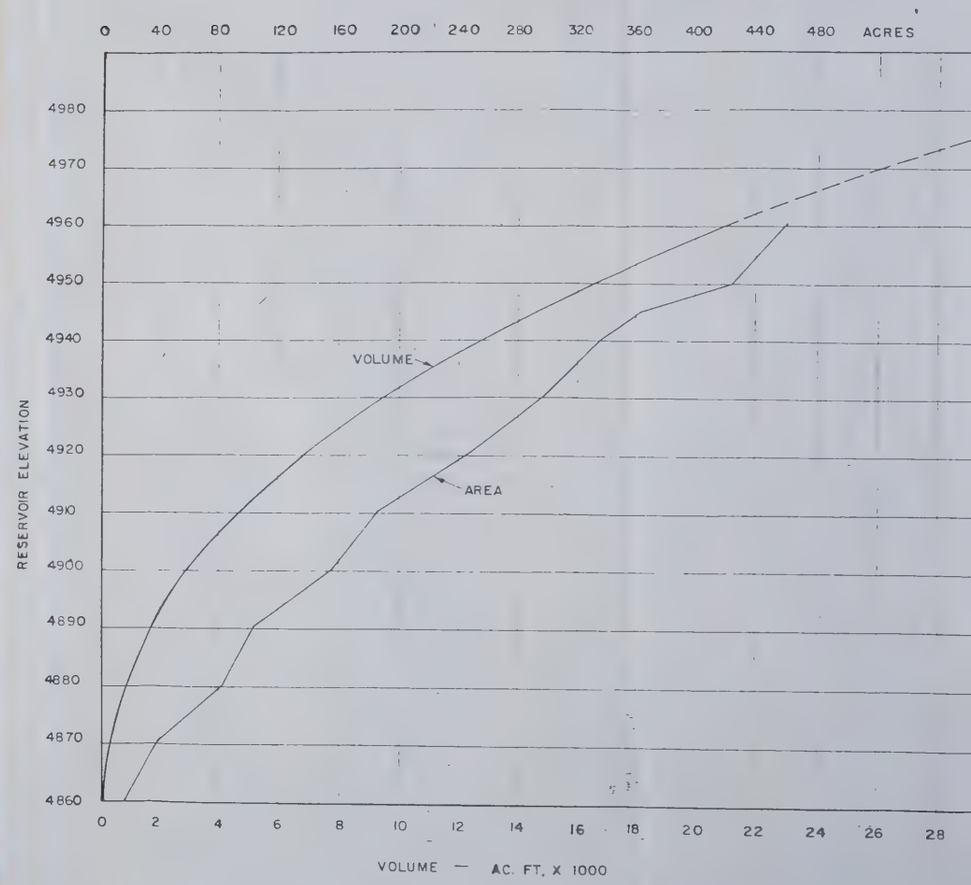
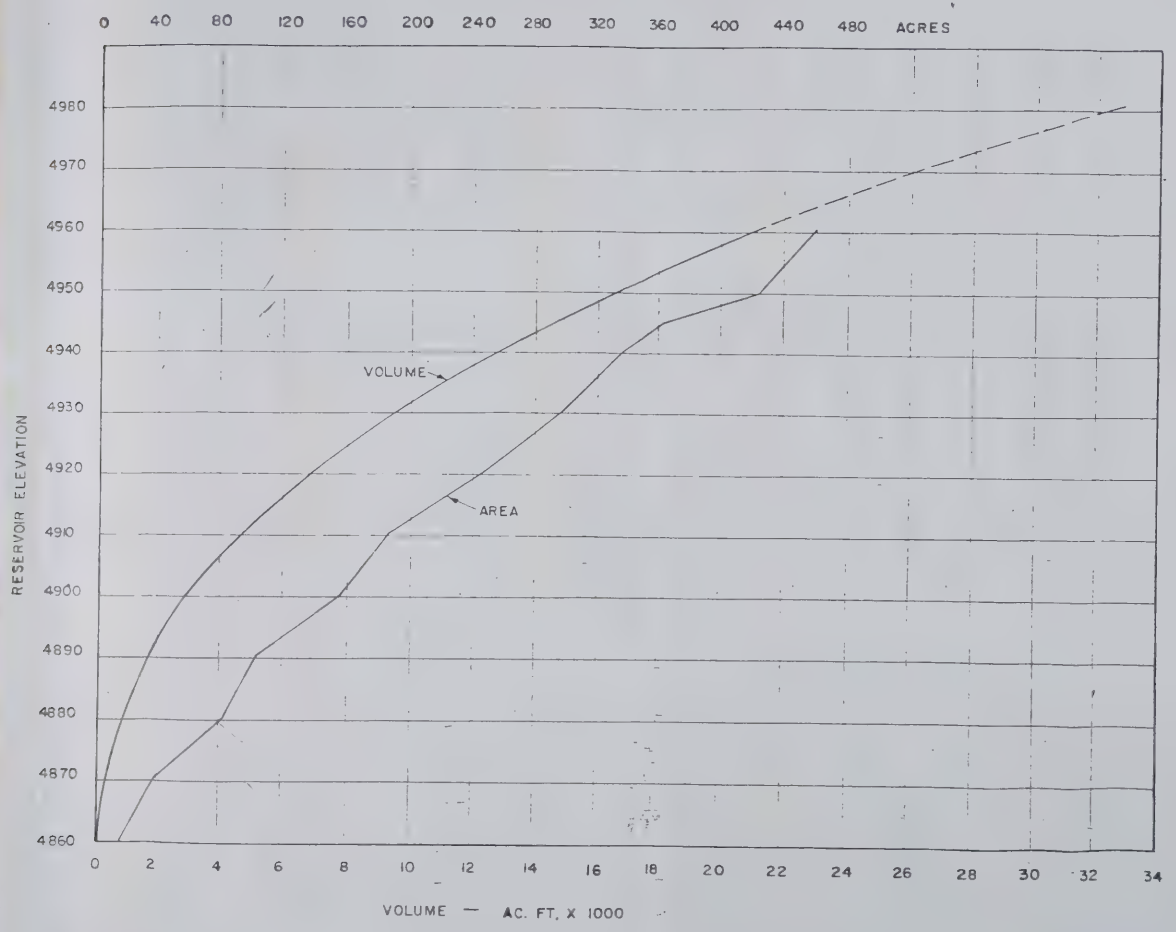


PLATE 5

POTENTIAL RESERVOIR AT MITCHELL SITE



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DEPARTMENT- WATER RESOURCES
PROVINCE OF ALBERTA

ELBOW RIVER REGULATION

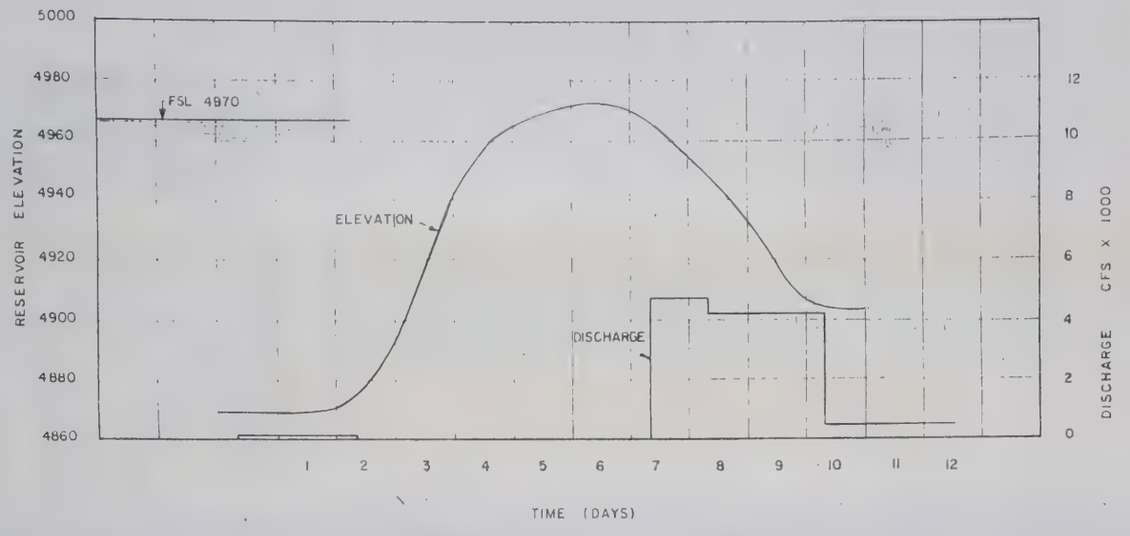
AREA AND STORAGE VOLUME CURVES

DESIGNED G D DRAWN C B DATE: OCT 1966

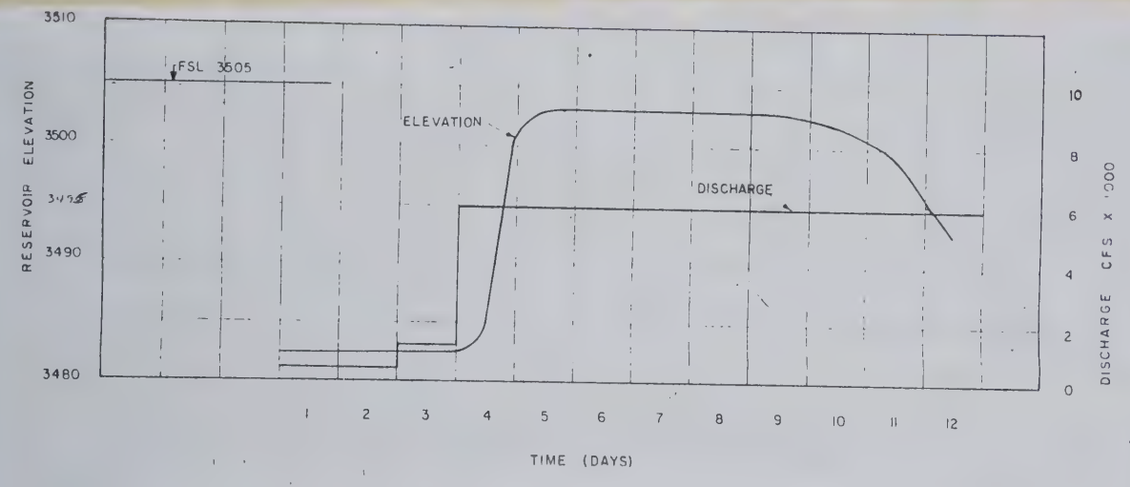
SUPERVISOR K G B PASSED gwEckenfelder

W O No AWR-1405-1 SCALE —

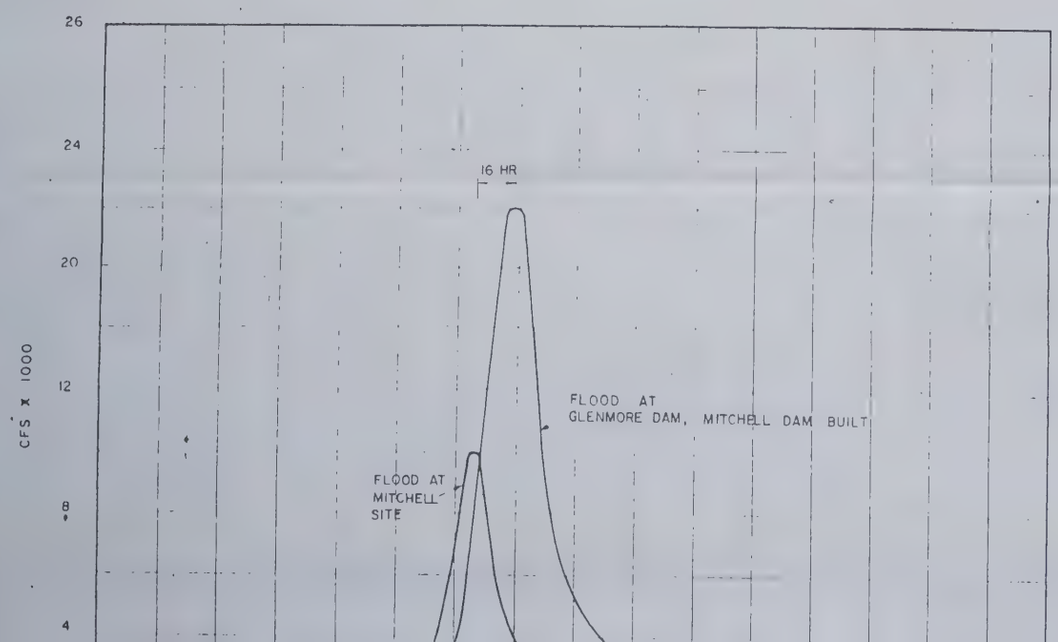
DWG. NO : D. AWR - 1013 - 5

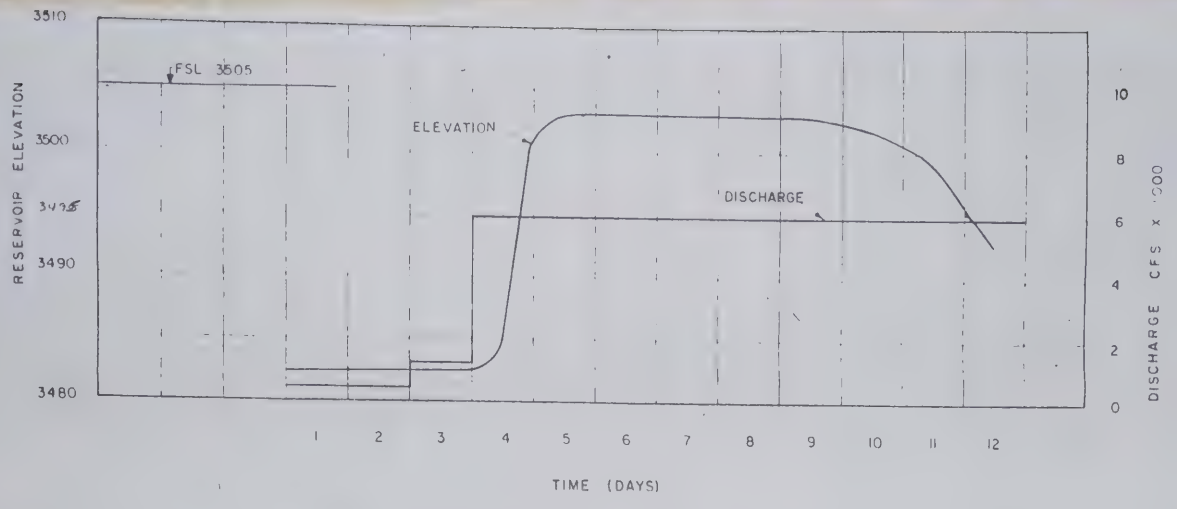


MITCHELL RESERVOIR ELEVATIONS
DURING 1·100 YEAR FLOOD

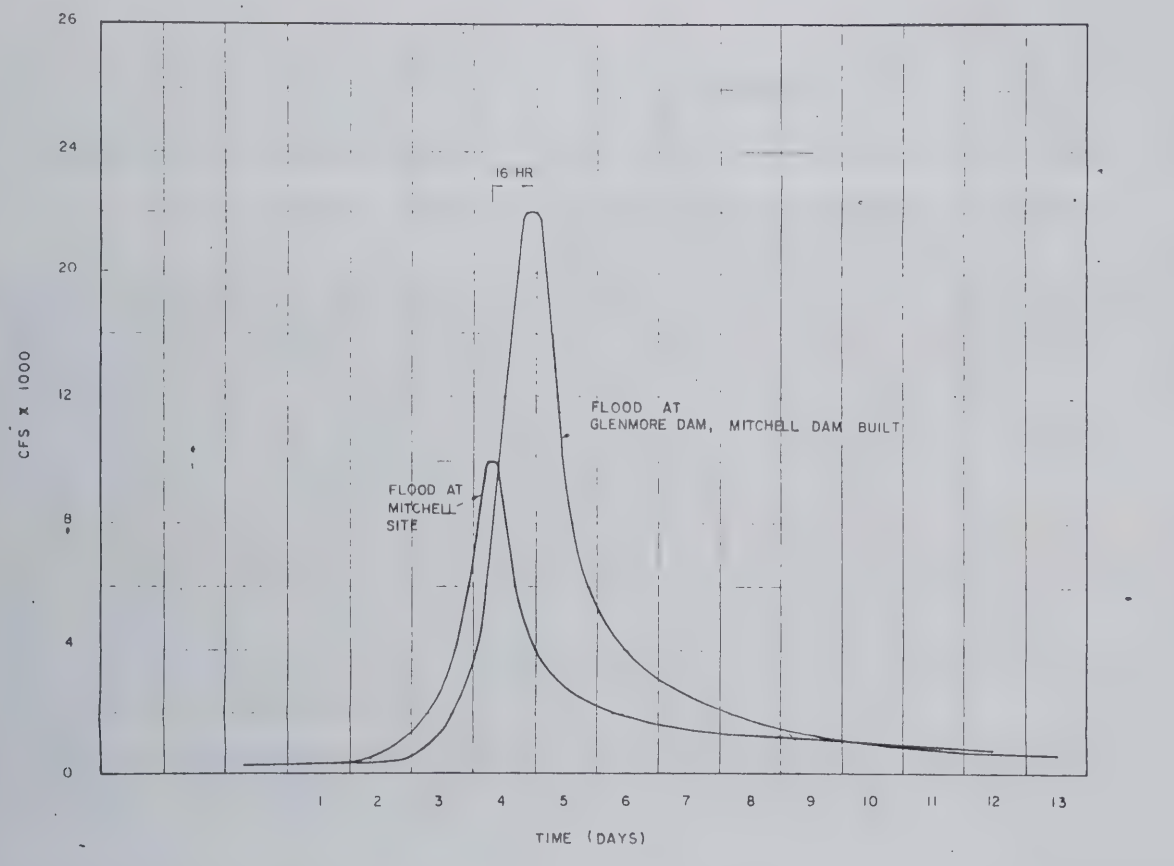


GLENMORE RESERVOIR ELEVATIONS
DURING 1·100 YEAR FLOOD,
MITCHELL DAM BUILT





GLENMORE RESERVOIR ELEVATIONS
DURING 1:100 YEAR FLOOD,
MITCHELL DAM BUILT



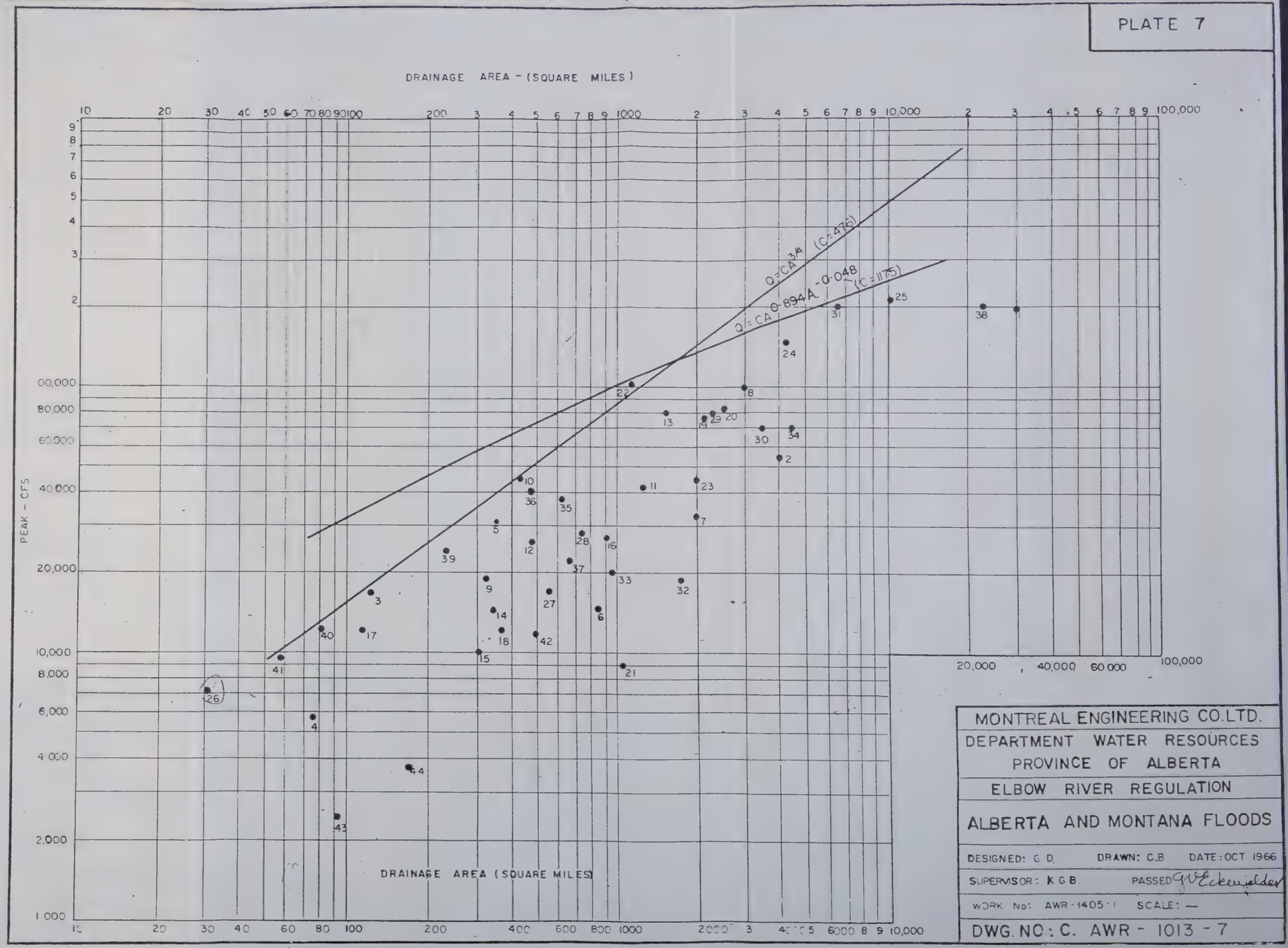
1:100 YEAR FLOOD HYDROGRAPHS

MONTREAL ENGINEERING CO. LTD.
DEPARTMENT WATER RESOURCES
PROVINCE OF ALBERTA
ELBOW RIVER REGULATION
RESERVOIR ELEVATIONS
1:100 YEAR FLOOD
DESIGNED: R.B. DRAWN: C.B. DATE: OCT. 1966
SUPERVISOR: K.G.B. PASSED:
W.O. No.: AWR-1405-1 SCALE: —
DWG. NO.: D-AWR-1013-6

PLATE 6

PLATE 7

1. ATHABASCA AT ATHABASCA
2. ATHABASCA AT ENTRANCE
3. BELLY AT MOUNTAIN VIEW
4. BELLY AT INTERNATIONAL BOUNDARY
5. BLACKSTONE
6. BOW AT BANFF
7. BOW AT SEEBE
8. BOW AT CALGARY
9. CASTLE AT BEAVER MINES
10. CASTLE AT COWLEY
11. CLEARWATER AT ROCKY MOUNTAIN HOUSE
12. ELBOW AT GLENMORE
13. FLATHEAD NEAR COL FALLS, MONTANA
14. GHOST NEAR COCHRANE
15. HIGHWOOD AT DIEBEL'S RANCH
16. HIGHWOOD AT ALDERSYDE
17. LEE AT CARDSTON
18. KANANASKIS NEAR SEEBEE
19. McLEOD AT EDSON
20. McLEOD AT WOLF CREEK
21. MILK RIVER AT MILK RIVER
22. M.F. FLATHEAD NEAR W. GLACIER, MONTANA
23. NORTH SASKATCHEWAN AT SAUNDERS
24. NORTH SASKATCHEWAN AT R.M.H.
25. NORTH SASKATCHEWAN AT EDMONTON
26. ELBOW AT BRAGG CREEK
27. OLDMAN AT WALDRONS CORNER
28. OLDMAN AT COWLEY
29. OLDMAN AT McLEOD
30. OLDMAN AT MONARCH
31. OLDMAN AT LETHBRIDGE
32. PEMBINA AT ENTWISTLE
33. RED DEER AT SUNDRE
34. RED DEER AT RED DEER
35. RAM
36. ST MARY'S AT INTERNATIONAL BOUNDRY
37. SHEEP AT ALDERSYDE
38. SOUTH SASKATCHEWAN AT MEDICINE HAT
39. WATERTON AT WATERTON PARK
40. BROWN
41. CHUNOO
42. NORTH SASKATCHEWAN AT SASKATCHEWAN CROSSING
43. MISTAYA
44. SHEEP AT BUCK



MONTREAL ENGINEERING CO. LTD.
DEPARTMENT WATER RESOURCES
PROVINCE OF ALBERTA
ELBOW RIVER REGULATION
ALBERTA AND MONTANA FLOODS

DESIGNED: G.D. DRAWN: C.B. DATE: OCT 1966
SUPERVISOR: K.G.B. PASSED G.W. Eckensfelder
WORK No: AWR-1405-1 SCALE: —
DWG. NO: C. AWR - 1013 - 7

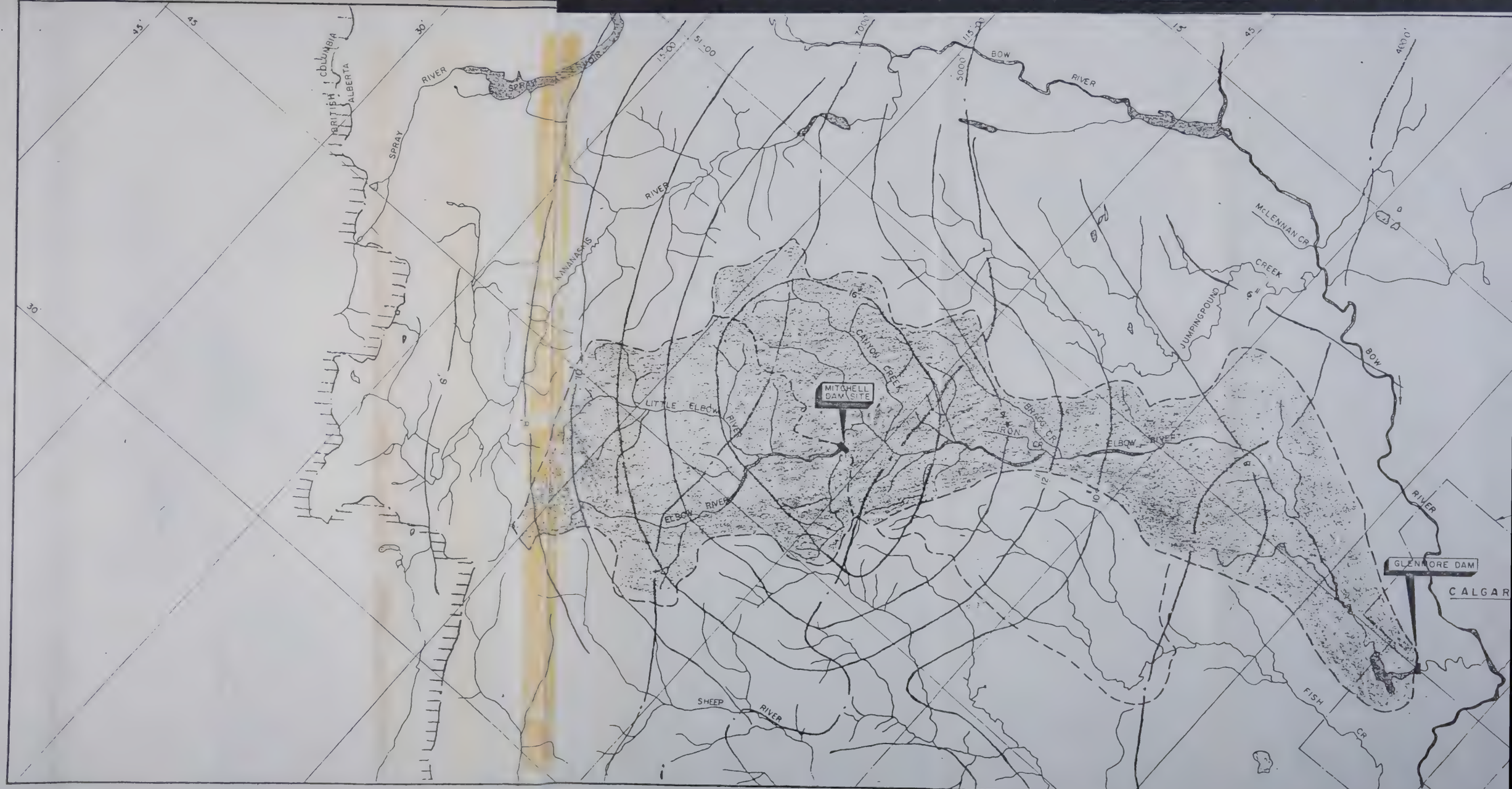
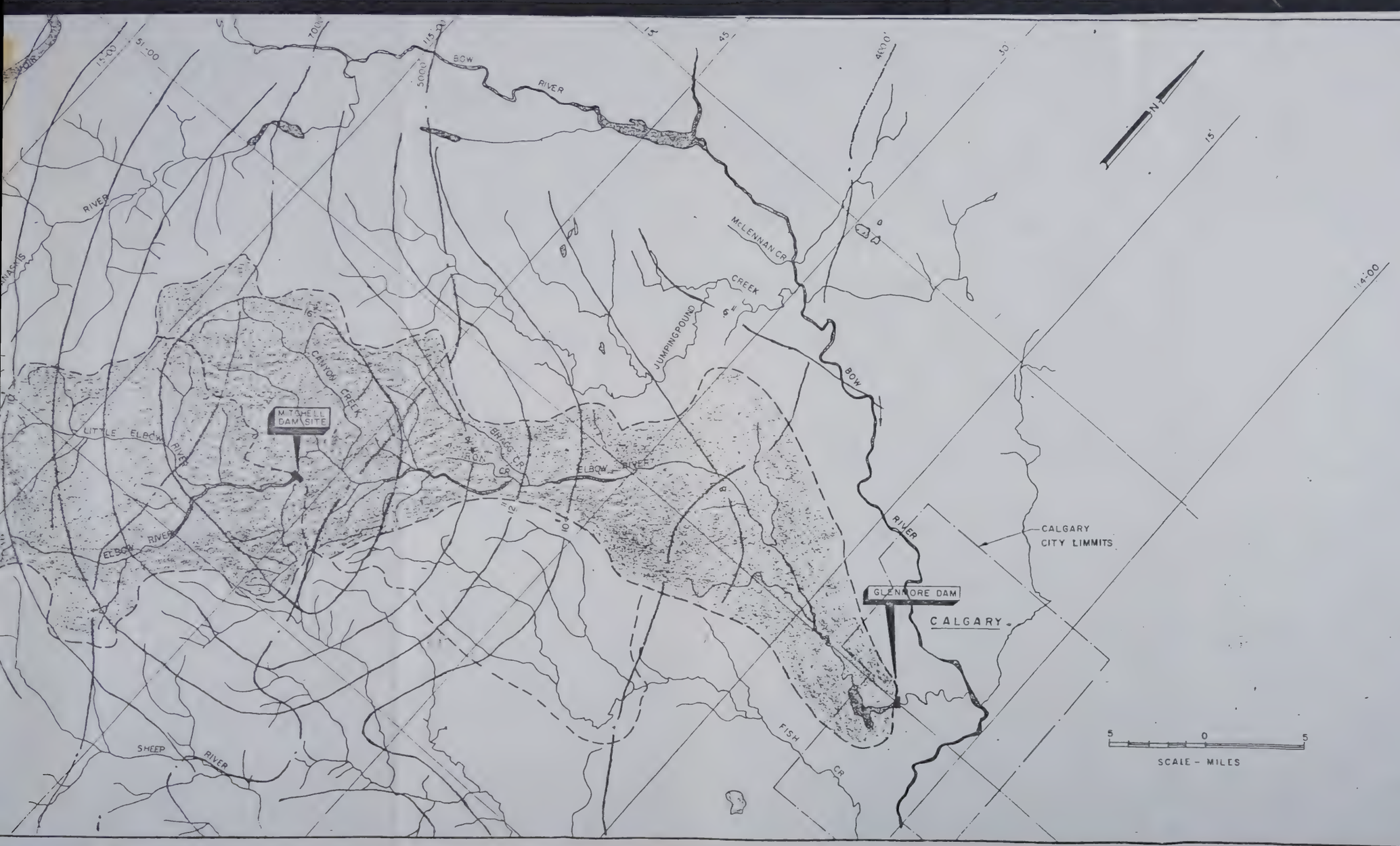

BRITISH COLUMBIA
ALBERTA
SPRAY RIVER
SPRAY RIVER
KANANASKIS RIVER
BOW RIVER
MITCHELL DAM SITE
LITTLE ELBOW RIVER
CANYON CREEK
IRON CR
BRIGGS CR
ELBOW RIVER
ELBOW RIVER
McLENNAN CR
JUMPINGPOUND CREEK
BOW RIVER
GLENMORE DAM
CALGAR
SHEEP RIVER
FISH CR

PLATE 8



LEGEND

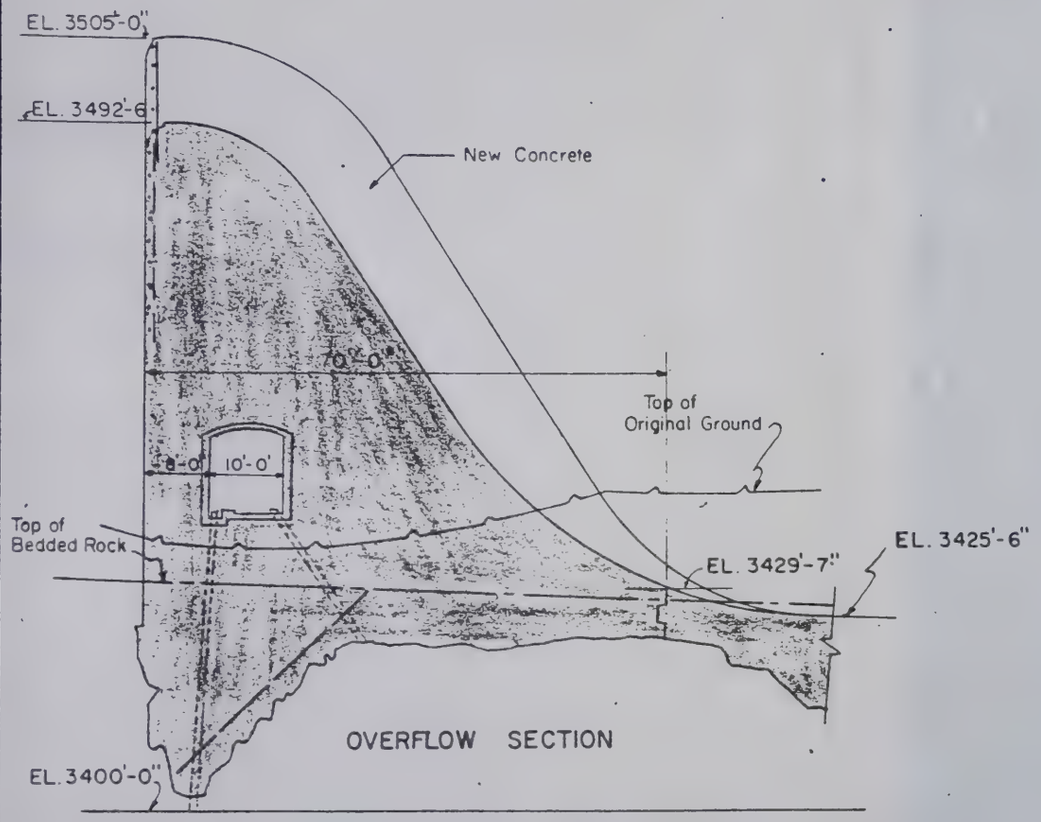
10" RAINFALL ISOHYETALS

APPROXIMATE ELEVATION

REFERENCE: NATIONAL TOPOGRAPHIC MAP 82J, B 82O

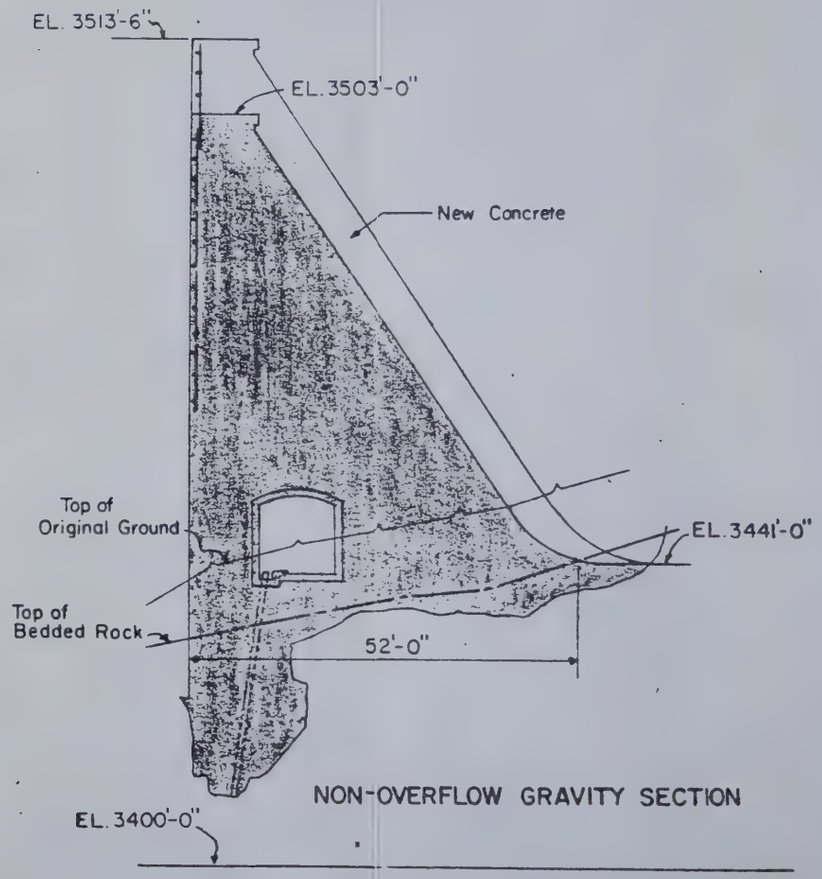
MONTREAL ENGINEERING CO. LTD.	
DEPARTMENT WATER RESOURCES PROVINCE OF ALBERTA	
ELBOW RIVER REGULATION	
TRANSPOSITION OF THE JUNE 1964 MONTANA STORM	
DESIGNED: G.D.	DRAWN: C.B. DATE: OCT. 1966
SUPERVISOR: K.G.B	PASSED:
W. O. No.: AWR-1405-1	SCALE: 1:250,000
DWG. NO.: D-AWR-1013-8	

PLATE 9



OVERFLOW SECTION

UNIT 12 AT STA. 93.0



NON-OVERFLOW GRAVITY SECTION

UNIT 5 AT STA. 48.0

PROPOSED MODIFICATIONS TO OVERFLOW AND GRAVITY SECTIONS OF THE GLENMORE DAM

'TRAFFIC BRIDGE NOT SHOWN'

Reference Dwg.:
Glenmore Reservoir-Dam
Dwg No R21, 17 Sept '31 (Calgary Water Works)
" " R19, 13 Jan. 32 (Calgary Water Works)

MONTREAL ENGINEERING CO. LTD.
DEPARTMENT WATER RESOURCES PROVINCE OF ALBERTA
ELBOW RIVER REGULATION
GLENMORE DAM MODIFICATIONS
DESIGNED: M.S. DRAWN: R.L. DATE: DEC 1966
SUPERVISOR: J.L.G. PASSED:
W. O. No.: AWR-1405-1 SCALE: 1" = 20'-0"
DWG. NO.: C- AWR - 1013 - 9

PLAN

SCALE 1" = 200'

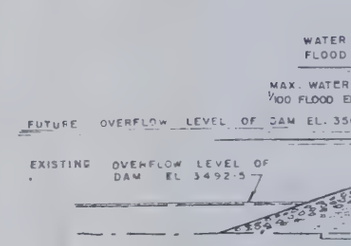
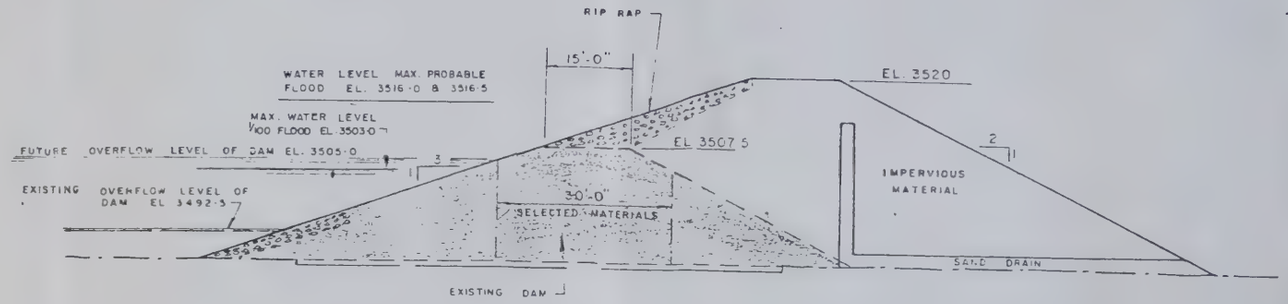


PLATE 10

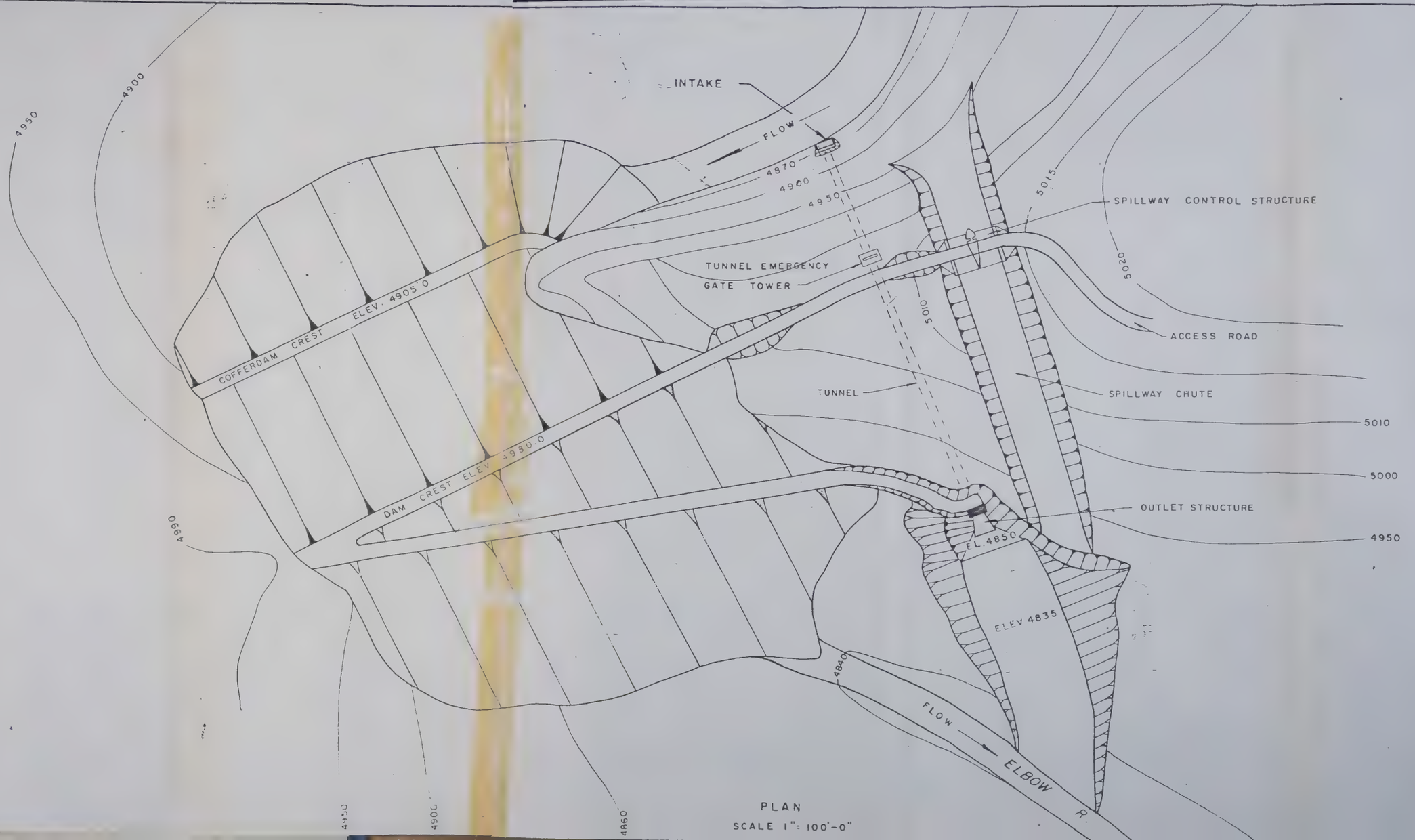


TYPICAL SECTION

SCALE 1" = 20'

FOR LOCATION OF DAM
SEE PLATE 1

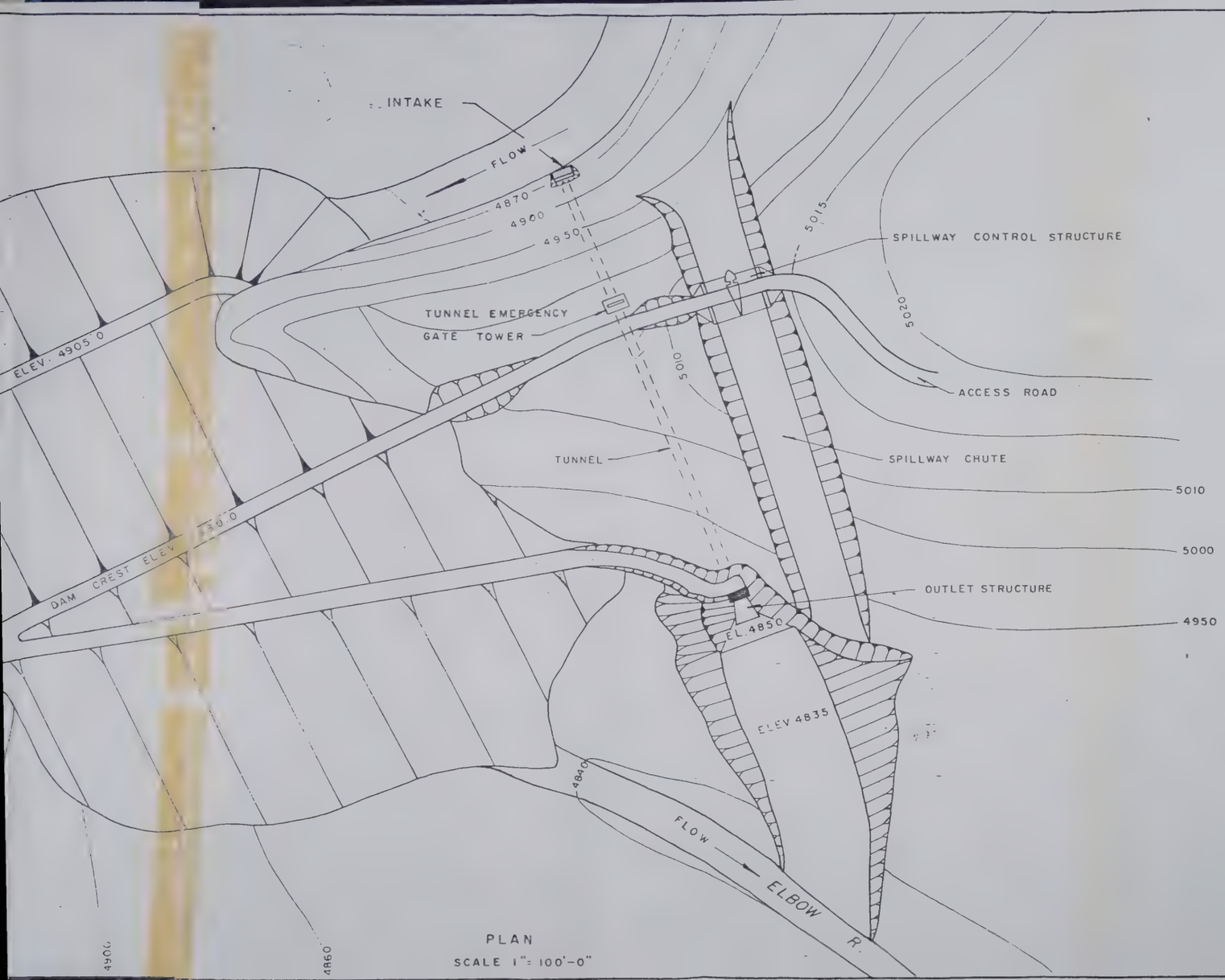
MONTREAL ENGINEERING CO. LTD.
DEPARTMENT WATER RESOURCES PROVINCE OF ALBERTA
ELBOW RIVER REGULATION
GLENMORE SIDE DAM MODIFICATIONS
DESIGNED: M.S. DRAWN: H.M.H. DATE: NOV '66
SUPERVISOR: J.L.G. PASSED: [illegible]
W. O. No.: AWR-1405-1 SCALE: NOTED
DWG. NO.: D-AWR-1013-10



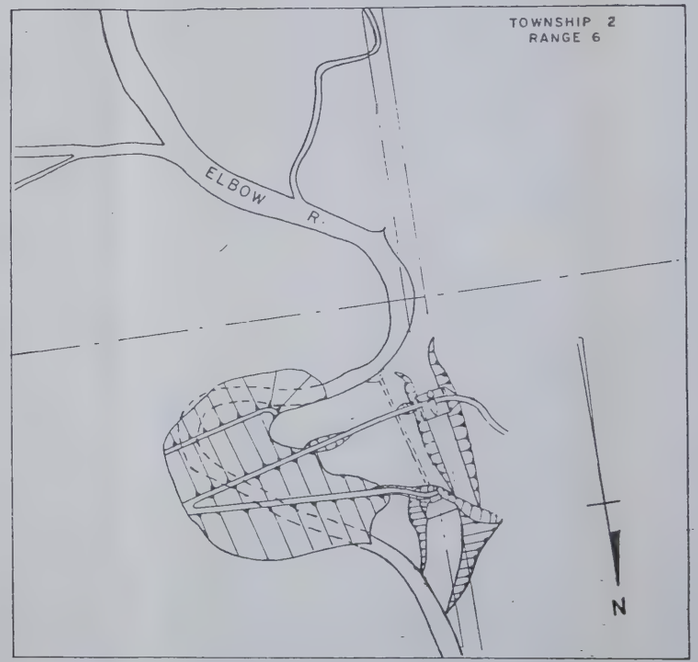
PLAN

SCALE 1"= 100'-0"

PLATE 11

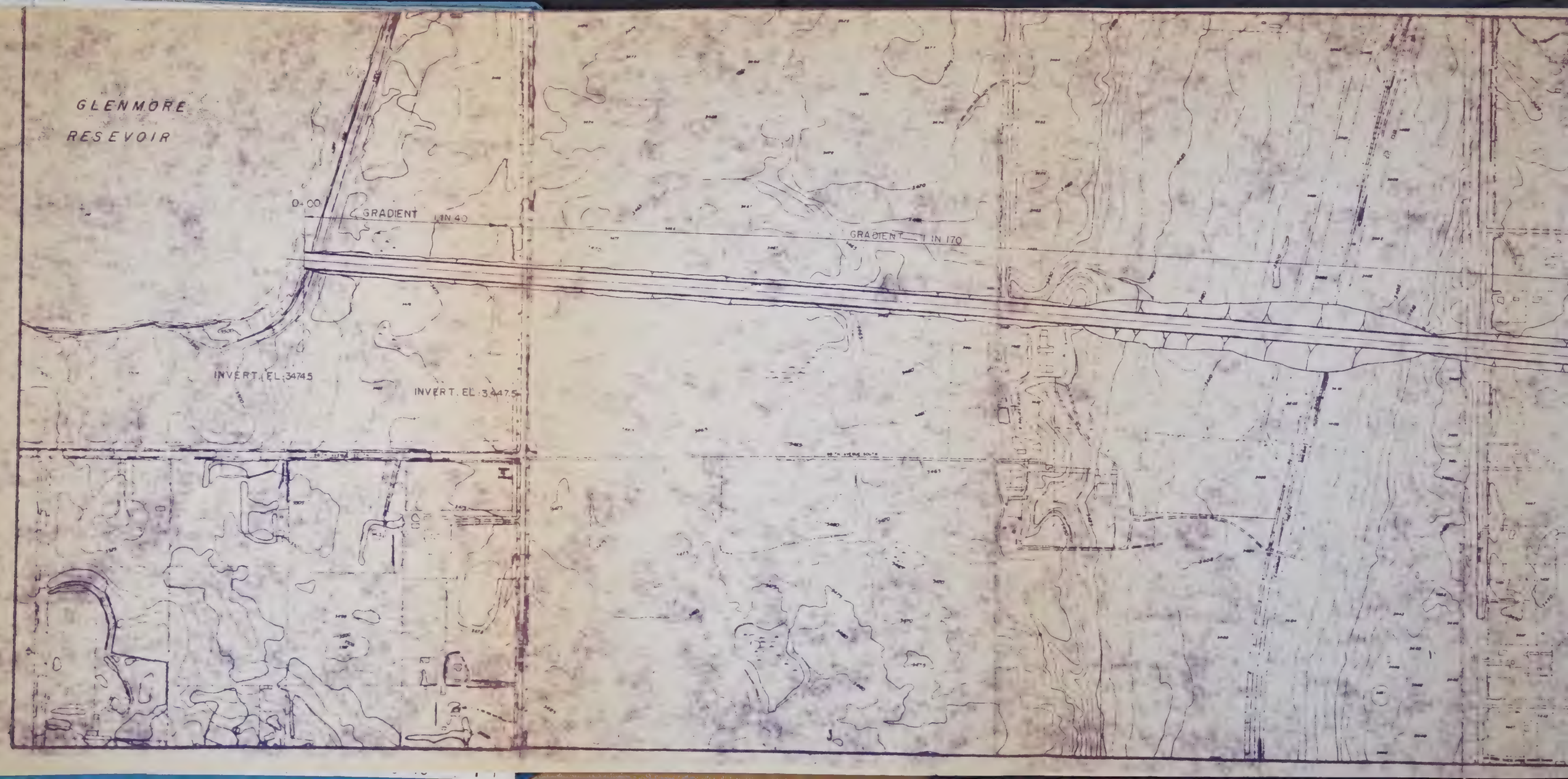


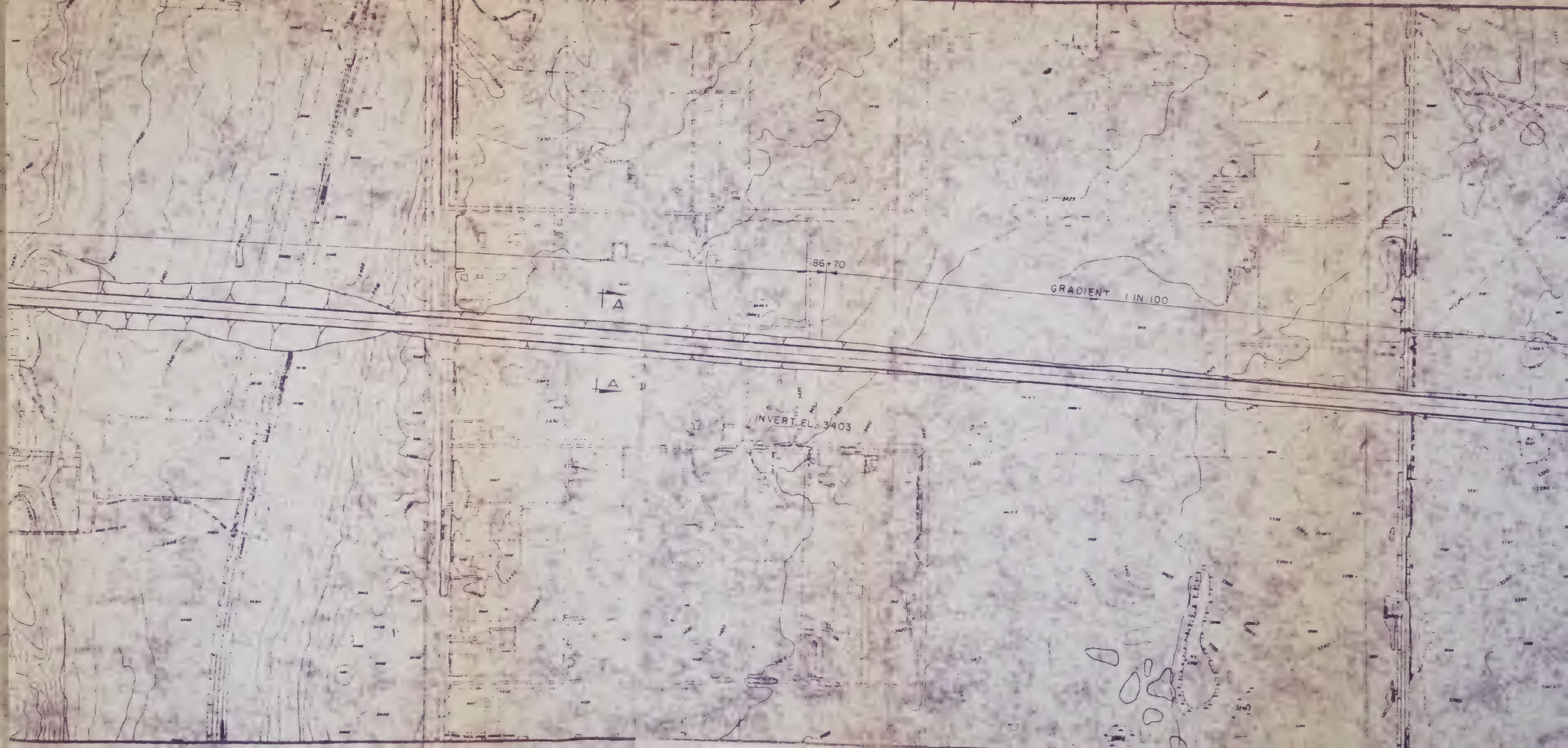
PLAN
SCALE 1"= 100'-0"



KEY PLAN
SCALE 1"= 400'

MONTREAL ENGINEERING CO. LTD.	
DEPARTMENT WATER RESOURCES PROVINCE OF ALBERTA	
ELBOW RIVER REGULATION	
LAYOUT - MITCHELL SITE	
DESIGNED: M. S.	DRAWN: H. M. H. DATE: DEC. 1966
SUPERVISOR: J. L. G.	PASSED:
W. O. No.: AWR-1405-1	SCALE: AS NOTED
DWG. NO.: D- AWR - 1013 - 11	


GLENMORE
RESEVOIR
0+00
GRADIENT 1 IN 40
GRADIENT 1 IN 170
INVERT. EL. 3474.5
INVERT. EL. 3447.5


86+70
GRADIENT 1 IN 100
INVERT EL. 3403

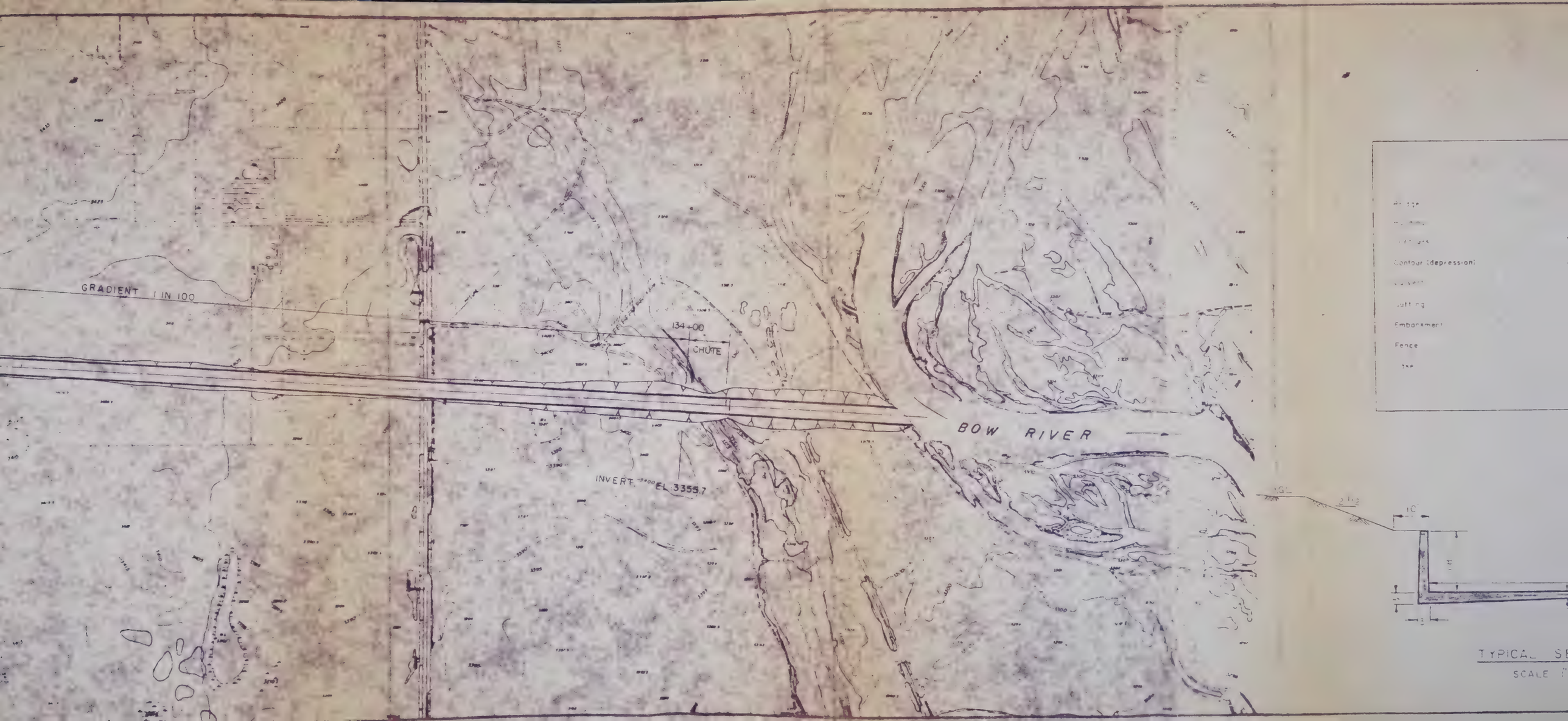
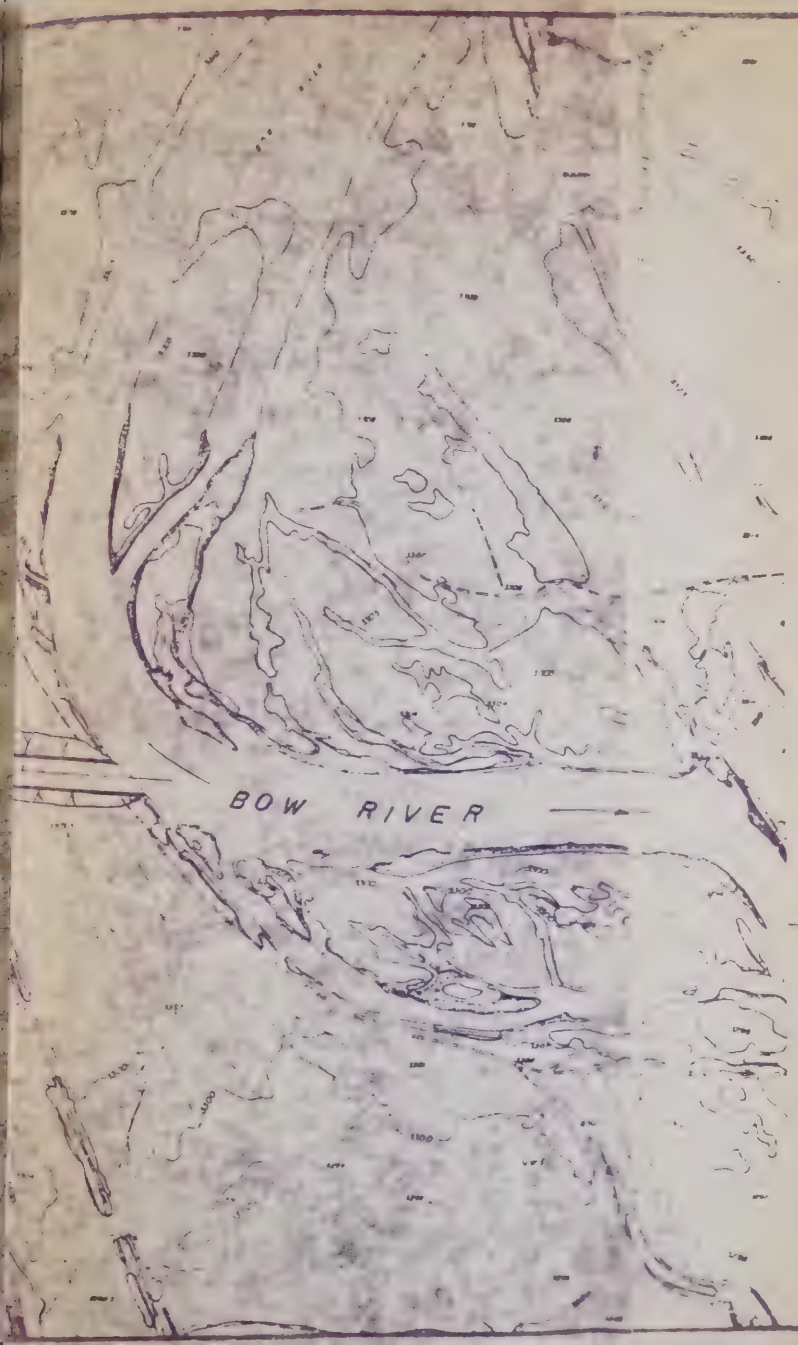

GRADIENT 1 IN 100
134+00
CHUTE
INVERT EL 3355.7
BOW RIVER
Contour (depression)
Cutting
Embankment
Fence
TYPICAL

PLATE 12

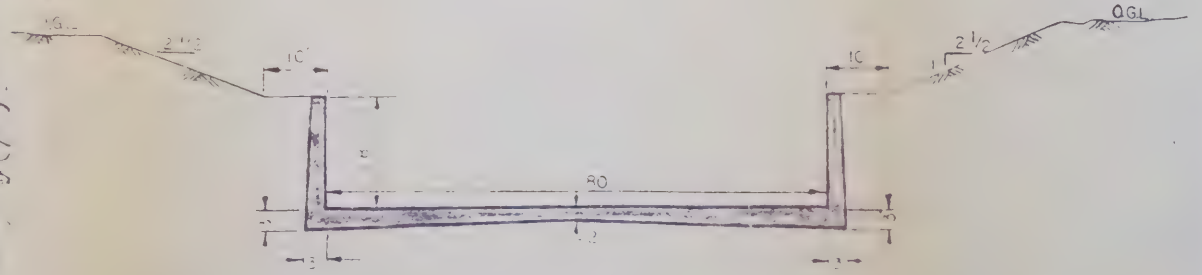


LEGEND

Bridge		Power or telephone line	
Building		Railroad	
Contour	3700	River	
Depression		Road	
Levee		Street	
Pipe		Stream	
Embankment		Swamp	
Fence		Trail	
Trap		Tree	

REFERENCE DRAWINGS

CITY OF CALGARY TOPOGRAPHICAL SERIES SECTIONS 17, 18, 19, 20, 15, 16, 21, 22, 4, 23, 9, 10



TYPICAL SECTION A-A

SCALE 20

MONTREAL ENGINEERING CO. LTD.	
DEPARTMENT WATER RESOURCES PROVINCE OF ALBERTA	
ELBOW RIVER REGULATION	
GLENMORE PLAN - SPILLWAY ALTERNATIVE	
DESIGNED:	DRAWN: DATE:
SUPERVISOR:	PASSED:
W. O. No:	SCALE:
DWG. NO.: D- AWR-103-2	

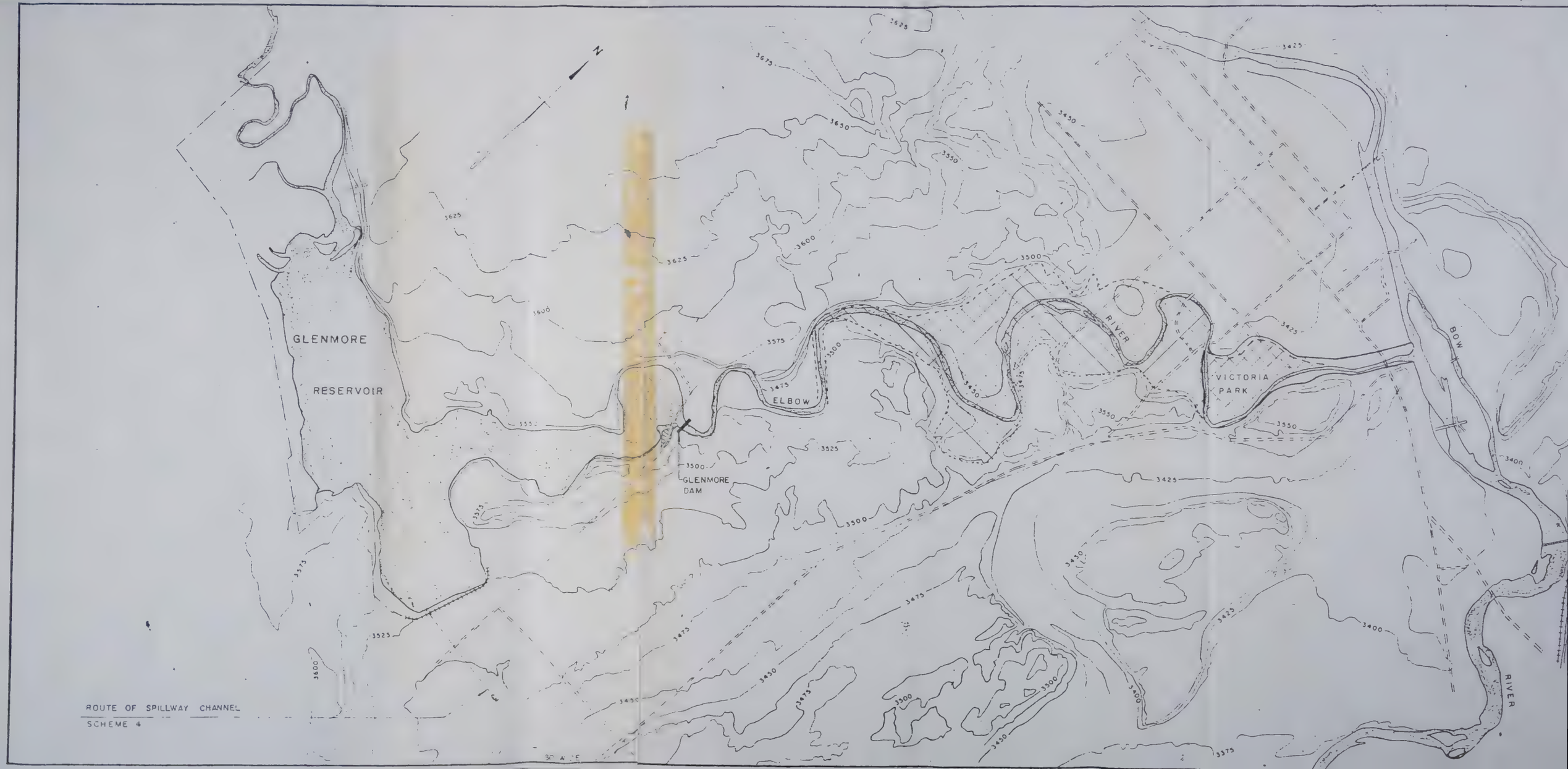
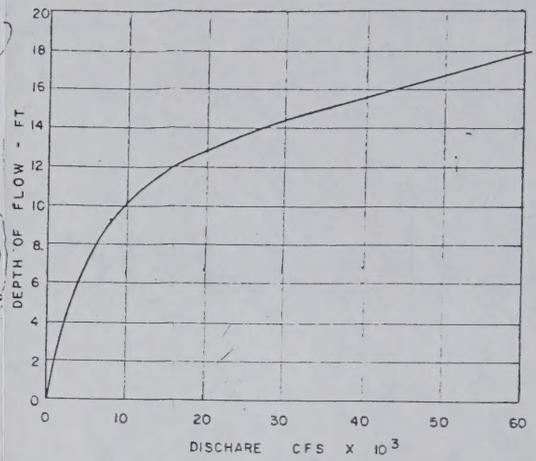

GLENMORE
RESERVOIR
ELBOW
GLENMORE
DAM
VICTORIA
PARK
BOW
RIVER
RIVER
ROUTE OF SPILLWAY CHANNEL
SCHEME 4

PLATE 13



STAGE - DISCHARGE CURVE - ELBOW RIVER

NOTE

ESTIMATED FLOODED AREA AT FLOW 47,500 C.F.S.

ESTIMATED FLOODED AREA AT FLOW 25,000 C.F.S. FROM REPORT BY T. BLENCH & ASSOCIATES.

0 1000 2000 FEET

SCALE

MONTREAL ENGINEERING CO. LTD.
DEPARTMENT WATER RESOURCES PROVINCE OF ALBERTA
ELBOW RIVER REGULATION
EXTENT OF FLOODING
DESIGNED: G.S. DRAWN: H.M.H. DATE: DEC 1966
SUPERVISOR: J.L.G. PASSED:
W.O. No.: AWR - 1405-1 SCALE: 1:525,000
DWG. NO.: D- AWR - 1013 - 13